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Groundfish Stock Assessments for the West Coast of Canada in 1989 and Recommended Yield Options for 1990

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ABSTRACT

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Stock assessments and yield options are developed for the Pacific coast of Canada for the following species: lingcod, Pacific cod, petrale sole, Dover sole, rock sole, English sole, arrowtooth flounder, sablefish, Pacific hake, spiny dogfish, walleye pollock, Pacific ocean perch, yellowmouth rockfish, rougheye rockfish, redstripe rockfish, silvergray rockfish, yellowtail rockfish, canary rockfish, quillback rockfish, copper rockfish, and yelloweye rockfish. The yield options are recommendations to the fishery managers of the Offshore Division of the Fisheries Branch on catch limitations and other fishery management procedures. Biological considerations only, rather than economic factors, are addressed in this document. The yield options are quantitative and are based on a series of appropriate mathematical methods, e.g., virtual population analysis, dynamic pool analysis, and Fournier stock-reconstruction procedures. Alternative options address the possibility of the fishery managers' considering high risk and low risk yields in relation to a stock's potential to produce.

Key words: groundfish, stock assessment, fishery yields

RÉSUMÉ

Tyler, A. V. and J. Fargo. 1990. Groundfish stock assessments for the west coast of Canada in 1989 and recommended yield options for 1990. Can. Tech. Rep. Fish. Aquat. Sci. 1732: 343 p.

Nous présentons des évaluations des stocks et différentes options concernant le volume des débarquements pour les espèces suivantes de la côte Pacifique du Canada: morue-lingue, morue du Pacifique, plie de Californie, sole à petite bouche, sole du Pacifique, sole anglaise, plie à grande bouche, morue charbonnière, merlu du Pacifique, aiguillat commun, goberge de l'Alaska, sébaste à longue mâchoire, sébaste à bouche jaune, sébaste à oeil épineux, sébaste à raie rouge, sébaste argenté, sébaste à queue jaune, sébaste canari, sébaste à dos épineux, sébaste cuivré et sébaste aux yeux jaunes. Les options concernant les débarquements sont des recommandations adressées aux gestionnaires des pêches de la Division hauturière de la Direction des pêches et ayant trait à la limitation des captures et autres pratiques de gestion des pêches. Cet article ne traite que des questions d'ordre biologique, et non pas des facteurs économiques. Nos options, d'ordre quantitative, sont fondées sur un ensemble de méthodes mathématiques pertinentes, comme l'analyse de la population virtuelle, l'analyse dynamique de regroupement et les méthodes de reconstitution des stocks de Fournier. Nous présentons d'autres options offrant aux gestionnaires des pêches la possibilité de choisir entre des rendements à haut risque et à faible risque établis en fonction du potentiel de production des stocks.

Mots clés: poissons de fond, évaluation des stocks, rendement des pêches

1.0 EXECUTIVE SUMMARY

1.1 INTRODUCTION

This document contains brief summaries of stock conditions of the important groundfish stocks, and recommendations for their management to the Offshore Division of the Field Services Branch. The report is prepared by the staff of the Groundfish Section of the Fisheries Research Branch, located at the Pacific Biological Station, Nanaimo, British Columbia, Canada V9R 5K6. Department biologists begin their assessments in the spring of the year using a multi-year data base for fishery statistics and biological research. A variety of assessment models are used including several sequential analysis models, age-independent surplus production models, yield-per-recruit, and linear models. Assessments are completed in August after review by a committee of DFO scientists. Review may also incorporate outside investigators (government or non-government), where desired by the DFO Research Branch. Assessments are then reviewed by the DFO Pacific Stock Assessment Review Committee (PSARC) and recommended yield options are collated and sent to the Offshore Division of the Fisheries Branch as guidance in the formulation of the annual Groundfish Management Plan.

1.2 LIST OF ASSESSMENTS

The following assessment texts are presented as chapters in this stock assessment document.

Lingcod--L. J. Richards and C. M. Hand
Pacific cod--A. V. Tyler and R. P. Foucher
Flatfish--J. Fargo
Sablefish--M. W. Saunders and G. A. McFarlane
Pacific hake--M. W. Saunders, L. J. Richards and A. V. Tyler
Dogfish--M. W. Saunders
Walleye pollock--M. W. Saunders
Slope rockfish--B. M. Leaman
Shelf rockfish--R. D. Stanley
Inshore rockfish--L. J. Richards and C. M. Hand

1.3 GENERAL CONDITION OF THE STOCKS

Views on current condition of groundfish species/species groups on the west coast of Canada are summarized in the table below. Since yield options are developed for 50 different stocks, only a general concept of species condition can be portrayed in this summary. A somewhat more complete account is given in Sections 1.4 and 1.5 of this Executive Summary. A table of recommended catch levels and management options is given in Section 1.7. The full reports follow as separate chapters.

Species or species group	Current stock condition
Strait of Georgia lingcod	Low
Offshore lingcod	Average
Pacific cod	Average
Petrale sole	Low
Rock sole, English sole	Average to high*
Dover sole, and arrowtooth flounder	Average to high*
Sablefish	Above average
Pacific hake	Average to high*
Spiny dogfish	Average to high*
Walleye pollock	Low to average*
Slope rockfish	Low to average*
Shelf rockfish	Average
Inshore rockfish	Low to average*

* depending on specific stock

1.4 MAJOR FISHERY CONCERNS

Concerns in the past year largely relate to the rockfishes. There is a disagreement between fishermen and biologists regarding the size of the standing stocks. The trawler captains believe that the stocks will support more catch than the annual quotas allow. Biologists have pointed out that the stocks are so slow-growing, that a large biomass is necessary in order to maintain the existing catch. There is both demonstrated and high potential risk of overfishing. Individuals are 8-15 years old before they spawn for the first time. If a quota is set too high on a trial basis for 5-6 years, and overfishing occurs, it will take 25 to 30 years to repair the stock. Pacific ocean perch and yellowtail rockfish are among the species of concern.

Groundfish research staff have met with the industry's Deep Sea Trawlers Association (DSTA) to try to develop a joint DFO-DSTA rockfish survey. The minimum objective is to form a relative abundance trend series that both industry and fisheries staff will believe. The procedures that are jointly agreeable are now in place. Discussions are being carried out to establish an industry fund for the surveys.

For inshore areas, rockfish species (quillback, copper, yelloweye rockfish) are being taken in some locations of the Queen Charlotte Strait, Johnstone Strait, and Strait of Georgia at rates greater than can be supported by natural production. Strait of Georgia lingcod have been over-exploited in the past and continue to be. There is evidence that the initial depletion of lingcod was due to the commercial fishery, but that the sports fishery now accounts for much of the present take, and must be controlled if rehabilitation is to ensue.

With the adoption of a coastwide management plan for Pacific ocean perch, the biologists and managers agreed to make special provisions for the Goose Island Gully stock in Queen Charlotte Sound, since this stock is below the standing biomass level that would produce maximum yield. Yet the stock is being fished at levels that are probably not sustainable. The high-risk sustainable level for the combined Goose Island-Mitchells Gullies is 1000 t, while the low-risk sustainable level is 700 t. The estimated perch catch for this area in 1988 was 1186 t. The fishery was not yet complete for 1989 at the time of writing, but the catch is expected to be about the same in 1989. Trawler captains have been very vocal on keeping the area open for a summer fishery despite the high catches that were made by July 1 in each of the last 2 years.

Yellowtail rockfish assessments were subject to a major review this year by a joint committee of U.S. and Canadian assessment biologists because of a transboundary issue. The main findings were that the fish do not mix on a coastwide basis as was thought. The Southwest Vancouver Island fish seem to mix with yellowtail rockfish in the U.S. fishery zone off Washington. The fish off Northwest Vancouver Island are subject to an active domestic trawl fishery, but the rate of mixing with either the U.S. portion of the distribution, or into Queen Charlotte Sound, remains indeterminate. The combined potential yield for Queen Charlotte Sound and Northwest Vancouver Island would range from 1900-4600 t, whereas the take from the domestic fishery off Southwest Vancouver Island should be limited to 300 t, in addition to the quantity taken in the Pacific hake fishery. A controversy will continue with U.S. managers regarding the magnitude of the total catch until the nature of the Northwest Vancouver Island distribution is resolved.

The sablefish fishery ran into difficulty this year when the 4000 t quota was taken prior to all K-licence vessels fishing in their registered, chosen openings. Managers decided to allow a quota overrun as an economic stop-gap measure. Alternative management approaches are being considered. Biologists are under pressure to increase the recommended annual quota because of increased CPUE. They are regarding this increase cautiously because the increase coincides with a change in management strategy for the fishery. An investigation of factors that could cause the increase is underway.

1.5 TEXT SUMMARIES OF ASSESSMENTS

Lingcod

Lingcod stocks were assessed with a size-structured model and by historical trends in CPUE. In addition, a new analysis indicated that size at 50% maturity is near 65 cm for female lingcod, well above the commercial size limit of 58 cm. Stocks were determined to be at extremely low levels in the Strait of Georgia portion of the Vancouver Area, and at moderate-high levels in the remainder of the Charlotte Vancouver Region. Yield projections were 1900-4000 t. An increase in the size limit from 58 cm to 65 cm is recommended coastwide, to be applied to all gear types. The increase is based on an analysis of size at maturity.

Pacific Cod

The stocks of Pacific cod in the Canadian Fishing Zone were all at average abundance levels. A new model was developed for the Hecate Strait stock, which produced 65% of the Canadian Pacific cod landings. All stock assessments, including the new age-structured model, are heavily based on standardized, commercial catch-at-age and catch per unit effort data. The special aspect of the new model was the use of a multivariate, second-order fitting technique that could account for the influence of water-mass advection and stock size on recruitment. The stock size fluctuated from 8,800 t to 17,600 t, but had a parent stock size of only 4,000 t that produced maximum annual surplus production (potential yield). This yield was estimated at 5,983 t in 1989, and 3,851 t in 1990. No catch limitations have been placed on the other Pacific cod stocks for 1990. The coastwide catch is not expected to exceed 7,000 t in 1990.

Flatfish

Flatfish stocks in 1989 were assessed on the basis of surplus production analysis of standardized landing statistics, trends in CPUE, and yield per recruit analysis. Petrale sole stocks were determined to be at low levels, rock sole stocks at high levels, and English sole and Dover sole stocks at moderate levels. Landing statistics for all rock sole stocks were standardized using a multiplicative model accounting for effects of vessel horsepower on CPUE. Recruitment of the 1985 year-class resulted in a significant increase in rock sole yield and sustainable yield estimates. English sole were assessed as a single stock in Hecate Strait for the first time. Yield per recruit analysis for English sole indicated that yield could be increased 30% if age of recruitment were 4 as opposed to 3.

Yields for various stocks of each species have the following coastwide ranges: Dover sole 800-2000 t, rock sole 100-1000 t, English sole 700-800 t.

Sablefish

Coastwide standardized CPUE values increased from 11.2 kg/trap in 1987 to 21.1 kg/trap in 1988. While this suggested that the stock was increasing in abundance, the change coincided with a change in management strategy for the fishery. An investigation of whether the increase was a result of increased recruitment, changing availability or an artifact of the new management scheme is currently underway.

Overall the condition of the sablefish stock in the Charlotte-Vancouver area is good. An age-structured forward simulation model was used to project biomass and yield, incorporating numbers-at-age from virtual population analysis (VPA) as the starting vector for the population. Yields ranging from 2,900 to 5,000 t were presented as low to high risk sustainable yield options for 1990.

Pacific Hake

In the Strait of Georgia portion of the Vancouver area, estimates of biomass during 1988, from swept-volume trawl and hydroacoustic surveys were 112,000 t and 73,300 t, respectively. These estimates compare favourably with identical surveys conducted in 1981. An assessment conducted using virtual population analysis (VPA) and a forward simulation model, indicated that yields up to 14,000 t may be sustainable. The analysis for the offshore stock was carried out in concert with U.S. biologists, and a range of 32,000 to 84,000 t was estimated for sustainable yields. The large range was partly due to options in the percentage split of the total potential yield between the U.S. and Canada.

Dogfish

Dogfish continued to support modest longline and trawl fisheries with a combined catch in the Vancouver and Charlotte areas of 4,904 t. Dogfish stocks were assessed using a deterministic age-structured model. The biomass in the Charlotte/Vancouver areas was estimated to be between 150,000-200,000 t. At current levels of harvest the stock was predicted to increase over the next 5-10 years. Coastwide yield levels ranged from 11,000 to 28,000 t.

Walleye Pollock

The 1988 pollock catch in the Canadian domestic fishery decreased from 1275 t in 1987 to 681 t in 1988. The 1988 incidental joint-venture and foreign catch decreased to 228 t from 1168 t in 1987. Canadian scientists surveyed the Strait of Georgia portion of the Vancouver zone in 1988, using swept-volume trawl and hydroacoustic techniques. Biomass was estimated to be between 9,069 and 22,500 t. Yields up to 5400 t are considered sustainable.

Slope Rockfish

Condition and yield potential of slope rockfishes (Sebastes alutus, S. reedi, S. aleutianus, and S. proriger) were assessed with methods including sequential age-structured, length-frequency simulation and stochastic recruitment models. In addition, some stocks were assessed solely on the basis of trends in fishery statistics or biological characteristics, due to data limitations. Stocks of Pacific ocean perch (S. alutus) were generally depressed and have shown no recovery from lowered abundances caused by high fishing mortalities applied during the mid-1960s. Coastwide yield estimates range from 3350-5470 t. Yellowmouth (S. reedi), rougheye (S. aleutianus) and redstripe (S. proriger) rockfishes were in moderate to poor condition with coastwide yield estimates of 1160-2450 t, 250-400 t, and 1450-3270 t, respectively. Redstripe rockfish was not subject to a management control program.

Shelf Rockfish

The yellowtail rockfish assessment was conducted with age-structured analysis. Yellowtail rockfish abundance in Queen Charlotte Sound appears to be increasing to virgin biomass levels following increased recruitment since 1974. The recommended yield range for the Queen Charlotte Sound stock is 1400-3600 t. Joint management with the U.S. is recommended for the southernmost population. Canary and silvergray rockfish stocks were assessed by examination of catch rates and length frequency simulation. Traditional fisheries for these stocks are minor (<1000 t/yr). Size and age composition indicates that they are already being harvested at rates equal to or greater than what is sustainable. Recommended yield ranges for 3 of the 5 major stocks are lowered slightly. The total recommended yield range for the five stocks is 2250-3150 t.

Inshore Rockfish

There has been a continued escalation of the line fishery for rockfish in the Vancouver-Charlotte Region. Stocks were assessed by historical trends in CPUE and by changing size and age structure of populations from commercial samples. Stock condition was determined to be poor in heavily exploited areas. Yields were estimated to range from 430-1590 t in 1989.

1.6 DEFINITIONS OF YIELD OPTIONS

A number of levels of yield options are presented. All may not be appropriate to apply to a particular species or stock. The seven yield options are: (i) zero yield; (ii) rebuilding yield; (iii) sustainable; (iv) low risk-sustainable; (v) high risk-sustainable; (vi) non-sustainable and (vii) unrestricted yield.

(i) Zero yield

This option could be entertained under situations of known and severe stock depletion, or where particular areas may represent necessary refuges for the fish. Additional ecological considerations might include situations where the subject stock acts as a predator on a less desirable species, and the objective is to maximize predation.

(ii) Rebuilding yield

Under this option the probability of overfishing is minimized while that of rehabilitating depleted stocks is increased. With the exception of option (i), this approach will incur the lowest risk of deleterious effects on stock biomass and dynamics. It is also true that it represents a lower yield than could be taken out of the stock on a sustainable basis. The most common application of this option is for stock rebuilding although for rockfish stocks this should be the approach to developing fisheries, because of the detection, response and corrective time frames (10-20 y) for rockfish species.

(iii) Sustainable yield

This option provides some opportunity to maintain stocks at existing levels. In many ways this is the least certain of the options available since it entrains many assumptions about the behaviour of stocks in response to fishing and biological processes. This option should be taken to mean that the probabilities of either decline or increase in yield (biomass) are approximately equal. The term "sustainable" should be understood in its broad sense, i.e., that the sustainable yield is constant only if there is no change in the balance among rates of somatic growth, recruitment, and natural mortality.

(iv) Low-risk sustainable yield

Like the Sustainable Option this is an estimate of the tonnage that can be caught during the year and leave enough of the biomass for the stock to replenish itself through reproduction and body growth. However, data are often not as complete as they should be for calculation of a single, firm estimate of the true value of the sustainable yield. When there is a high degree of uncertainity about the estimate, a cautious approach to setting the catch limits should be taken. The cautious or conservative estimate is often set simply as 50% or 75% of the calculated sustainable yield, depending on the biologist's understanding of the reliability of the estimate.

(v) High-risk sustainable yield

This catch limit has some small chance of being a sustainable yield. The estimate is at the other end of the range from the low risk-sustainable yield, and is above the Sustainable yield estimate. The level is often set simply as 25% or 50% higher than the sustainable yield value. Sometimes a central value for the sustainable yield is not given, only the low risk and high risk levels. High risk levels should only be selected to provide relief from a specific case of economic hardship, with conscious recognition being made that decreases to sustainable levels in the near future might be the result of selecting this option.

(vi) Non-sustainable yield

While the sustainable option is derived from the biological properties of the species and stock composition, the non-sustainable level is largely an economic and management concept. The benefits of increased yield over the short term must be weighed against the lowered future yields resulting from overfishing. Employment of this option implies either experimental or non-biological management, since stock declines are highly probable with such a policy in effect over a significant part of the average life of a population cohort. This option might be considered when: socio/economic conditions require short-term yields in excess of sustainable harvest; experiments concerning well defined and disparate exploitation rates are necessary; or, management policy requires sequential, pulsed fishing on several stocks.

This option requires that management will have to shift to a conservative policy to offset deleterious effects prior to major and irreversible stock changes. Thus, this option either guarantees a pulsed exploitation pattern if the stock is to be maintained at the most productive level, or accepts short-term gains over long-term productivity.

The hazard associated with this option will vary with the biological characters of the target stocks. In particular, the residence time of a cohort in the vulnerable stock will be a key determinant in the time for detection and response. Where residency is long, higher than sustainable yields may be maintained over several years in spite of strongly deleterious, yet undetected effects on subsequent cohorts. Conversely, a short residency may permit more rapid detection of adverse effects although incremental increases in quotas should be small if uncertainty about effects is high.

(vii) Unrestricted yield

Few conditions would call for consideration of this option. Depletion of stocks and elimination of fisheries when harvests are uncontrolled are well documented throughout the world. However, this option might be considered for experimental purposes or for stock eradication in the case of competing species.

(viii) Other measures

The trawl fishery for groundfish is characterized by a multi-species catch. Managers, biologists, and vessel captains have noted that there are two principal difficulties created because of the multi-species characteristics. (1) Biological interactions among species may interfere with the simultaneous maximization of fisheries potential yield in all co-existing species. (2) Where there are several annual quotas on a group of co-existing species, the species quota that is taken first could close down fishing on the entire group. At present biological interactions are not explicitly built into the stock assessments. This is cause for avoiding the risk-sustainable options if at all possible. On the other hand, regarding problem 2, multi-species yield options are arranged so that premature closure for a whole group of species is unlikely. Trip limits have been used to spread the take of lower production species through the year. In a few cases, species-mixture or group quotas are given, and an area not closed until the group quota is reached. Species ratios are checked for imbalance. If a gross imbalance is found, the group quota is adjusted the following year.

1.7 DEFINITIONS FOR CATCH STATISTICS

In the past we have used the terminology "Landings" to mean round weight of fish landed by vessels in port. This has logically led to the term "Landings per unit effort" as an index of catch rate. Because some confusion has resulted from use of these terms, and because other standard terms are used by FAO, ICES, NAFO, as well as most marine fisheries biologists of the Canadian Atlantic community, we have decided to shift to the FAO standard terms. In this stock assessment document we have used the terms NOMINAL CATCH and NOMINAL CPUE (or just CPUE) following the FAO definitions.

We take the following definition from the FAO Yearbook of Fishery Statistics: "The concept of NOMINAL CATCH refers to the landings converted to a live weight basis. The closely related concept LANDINGS refers to the quantities on a landed weight basis... There are many instances where the catches on board fishing vessels or factory ships are gutted, eviscerated, filleted, salted, dried, etc." Thus, landings come in a variety of forms.

We recognize that whole, or round fish weight measured in port as nominal catch is not preciselty the live weight of the fish as specified in the FAO statistics yearbook. When fish are iced, or refrigerated in chilled brine as is the custom with many vessels of the west coast of Canada, an individual fish takes on a small amount of extra weight due to an increase in water content.

1.8 Recommendations for management of west-coast groundfish for 1990 based on biological considerations only are summarized below.

Area	Species	Management options
4B	Lingcod	1. Experimental Sub-area closures. 2. Total closure of sport and commercial fisheries. 3. Introduce minimum size limit of 65 cm for commercial and sport-caught lingcod to protect immatures.
3C	Lingcod	1. Winter closure Nov. 15-Apr. 30. 2. Low risk-sustainable: 1000 t. 3. Sustainable: 1400 t 4. High risk-sustainable: 2000 t. 5. Size limit of 65 cm.
3D	Lingcod	1. Winter closure Nov. 15-Apr. 30. 2. Size limit of 65 cm. 3. Low risk: 300 t. 4. Sustainable: 400 t. 5. High risk: 600 t.
5A/B	Lingcod	1. Size limit of 65 cm for commercial fishery. 2. Low risk: 600 t 3. Sustainable: 900 t 4. High risk: 1400 t
5C/D/E	Lingcod	No options proposed.
4B	Pacific cod	No options proposed.
3C/3D	Pacific cod	Open fishing due to average abundance.
5A/5B	Pacific cod	No options proposed.

Area	Species	Management options
5C/5D	Pacific cod	1. Low risk sustainable: 2800 t. 2. Sustainable: 3800 t. 3. High risk sustainable: 4800.
5E	Pacific cod	No options proposed.
Coastwide	Petrale sole	1. Sustainable: trip limit 4,000 lb.
4B	Flatfish	No options proposed
3C/D	Dover sole	Low risk sustainable: 1000 t. Sustainable: 1500 t. High risk sustainable: 2000 t.
5A	Rock sole	1. Low risk sustainable: 100 t (with 30,000 lb trip limit). 2. Sustainable: 175 t. 3. High risk sustainable: 250 t.
5B	Rock sole	1. Low risk-sustainable: 200 t, 30,000 lb trip limit. 2. Sustainable: 300 t, 30,000 lb trip limit. 3. High risk-sustainable: 400 t.
5C	Rock sole	1. Low risk-sustainable: 500 t, 30,000 lb trip limit. 2. Sustainable: 550 t, 30,000 lb trip limit. 3. High risk-sustainable: 700 t.

Area	Species	Management options
5D	Rock sole	1. Low risk-sustainable: 700 t, 20,000 lb. trip limit; or 30,000 lb, 2 trips/mo. 2. Sustainable: 850 t, trip limits as in 1. 3. High risk-sustainable: 850 t.
5C/D	English sole	1. Low risk-sustainable: 700 t. 2. Sustainable: 750 t 3. High risk-sustainable: 800 t.
5C/5D/5E	Dover sole	1. Low risk-sustainable: 800 t quota, 20,000 lb/trip permitted after 75% of the quota is reached. 2. High risk-sustainable: 1,000 t quota 20,000 lb/trip permitted after 75% of the quota is reached.
Coastwide	Sablefish	1. Low risk-sustainable: 2,900 t quota. 2. Sustainable: 4,000 t. 3. High risk-sustainable: 5,000 t quota.
4B, not including MSA 19, 20	Pacific hake	1. Low risk-sustainable: 8,000 t. 2. Sustainable: 11,000 t. 3. High risk-sustainable: 14,000 t.

Area	Species	Management options
3C	Pacific hake	1. Low-risk sustainable: 32,000 t. 2. Sustainable 50,000 t. 3. High-risk sustainable: 70,000 t*. *as high as 84,000 t depending on CDN/U.S. % allocation.
Coastwide	Dogfish	1. Pulse fishing: variable annual annual (not including 4B) quota until non-nuisance abundance 2. Low risk-sustainable: 15,000 t in 3 and 4 quarter of year only. 3. Low risk-sustainable alternative: 9,000 t in 1 and 2 quarter of years only. 4. High risk-sustainable: 25,000 t in 3 and 4 quarter only. 5. High risk-sustainable alternative: 15,000 t in 1 and 2 quarter of years only.
4B, not including MSA 12, 19, 20.	Dogfish	1. Low risk sustainable: annual 2,000 t. 2. Sustainable: 2,500 t. 3. High risk-sustainable: 3,000 t.
4B	Walleye pollock	1. Low risk-sustainable: 2,500 t quota. 2. High risk-sustainable: 5,400 t quota.
3C/3D	Walleye pollock	Options not proposed.

Area	Species	Management options
5A/5B	Walleye pollock	Options not proposed.
5C/5D	Walleye pollock	Open fishing option proposed.
5E	Walleye pollock	Options not proposed.
3C	Yellowtail rockfish	Joint management with U.S. (Interim domestic fishery ceiling quota): 300 t.
5A/5B	Yellowtail rockfish	Low risk sustainable: 1400 t. High risk sustainable: 3600 t.
5C/5D/5E	Yellowtail rockfish	Low risk sustainable: 160 t. High risk sustainable: 500 t.
3C/3D	Silvergray rockfish	Low risk-sustainable: 400 t. High risk-sustainable: 600 t.
5A/5B	Silvergray rockfish	Low risk sustainable 700 t. High risk-sustainable: 850 t.
5C/5D	Silvergray rockfish	Low risk sustainable 400 t. High risk-sustainable: 600 t.

Area	Species	Management options
5E-S	Silvergray rockfish	No recommendation. Currently an incidental fishery.
5E-N	Silvergray rockfish	No recommendation. Currently an incidental fishery.
3C/3D	Canary rockfish	Low risk-sustainable: 400 t. High risk-sustainable: 600 t.
5A/5B	Canary rockfish	Low risk-sustainable: 350 t. High risk-sustainable: 500 t.
5C/5D	Canary rockfish	Low risk-sustainable: Unknown High risk-sustainable: 500 t.
5E-N/S	Canary rockfish	Low risk-sustainable: Unknown High risk-sustainable: 500 t.
3C options (including Area 125)	Pacific ocean perch	1. Rebuilding: <100 t. 2. Low risk-management sustainable: 100 t. 3. High risk-sustainable 200 t.
3C	Redstripe rockfish	Low risk-sustainable: 200 t. High risk sustainable: 1,000 t.

Area	Species	Management options
3D	Pacific ocean perch	Low risk-sustainable: 200 t. High risk-sustainable: 600 t.
3D/5A	Yellowmouth	Low risk-sustainable: 250 t. High risk-sustainable: 750 t.
3D/5A	Redstripe	Low risk-sustainable: 350 t. High risk-sustainable: 900 t.
5A/5B	Pacific ocean perch	Rebuilding: <700 t. Low risk-sustainable: 700 t. High risk-sustainable: 1,000 t.
5C/5D	Pacific ocean perch	Low risk-sustainable: 1,900 t. High risk-sustainable 3,000 t.
5C/5D	Yellowmouth	Low risk-sustainable: 160 t. High risk-sustainable: 500 t.
5C/5D	Redstripe	Low risk-sustainable: 350 t. High risk-sustainable: 570 t.
5E-S	Pacific ocean perch	Low risk-sustainable: 300 t. High risk-sustainable: 500 t.
5E-S	Yellowmouth	Low risk-sustainable: 400 t. High risk-sustainable: 700 t.
5E-S	Rougheye	Low risk-sustainable: 200 t. High risk-sustainable: 300 t.

Area	Species	Management options
5E-S	Grouped slope rockfish (Pacific ocean perch, yellowmouth and rougheye)	January-June Low risk-sustainable: 300 t. High risk-sustainable: 500 t. September-December Low risk-sustainable: 600 t. High risk-sustainable: 1,000 t.
5E-S	Redstripe	Low risk-sustainable: 50 t. High risk-sustainable: 100 t.
5E-N	Pacific ocean perch	Low risk-sustainable: 150 t. High risk-sustainable: 170 t.
5E-N	Yellowmouth	Low risk-sustainable: 350 t. High risk-sustainable: 500 t.
5E-N	Rougheye	Low risk-sustainable: 50 t. High risk-sustainable: 100 t.
5E-N	Redstripe	Low risk-sustainable: 500 t. High risk-sustainable: 700 t.
4B-MSA-12	Copper/ Quillback	Low risk-sustainable: 75 t. High risk-sustainable: 125 t.
4B-MSA-13	Copper/ Quillback	Low risk-sustainable: 50 t. High risk-sustainable: 100 t.
4B-MSA-14-20, 28,29	Copper/ Quillback	Low risk-sustainable: 100 t. High risk-sustainable: 150 t.
4B	Yelloweye	Low risk-sustainable: 25 t. High risk-sustainable: 75 t.

Area	Species	Management options
3C/D	Grouped line rockfish	Low risk-sustainable: 60 t. High risk-sustainable: 370 t.
5A/B/C/D/E	Grouped line rockfish	Low risk sustainable: 120 t. High risk sustainable: 770 t.

REVIEWER ASSIGNMENTS FOR GROUNDFISH STOCK ASSESSMENTS

Title	Authors	Reviewers
Lingcod	L. Richards, C. Hand	J. Fargo, M. Saunders
Pacific cod	A. Tyler, R. Foucher	R. Stanley, C. Wood
Flatfish	J. Fargo	L. Richards, R. Stanley
Sablefish	M. Saunders	C. Hand, B. Leaman
Dogfish, walleye pollock	M. Saunders	A. Tyler
Pacific hake	M. Saunders	L. Richards, A. Tyler
Slope rockfish	B. Leaman	J. Fargo, M. Saunders
Shelf rockfish	R. Stanley	R. Foucher, D. Noakes
Inshore rockfish	L. Richards, C. Hand	R. Foucher, B. Leaman

PARTICIPANTS AT THE GROUNDFISH SUBCOMMITTEE MEETING
August 31-September 1, 1989

A. Tyler, Chairman
D. Adams
G. Beuchler
J. Fargo
S. Farlinger
R. Foucher
C. Hand
R. Harbo
B. Leaman
D. McKone
G. McFarlane
M. Saunders
R. Stanley
L. Richards
N. Venables
C. Wood
E. Zyblut

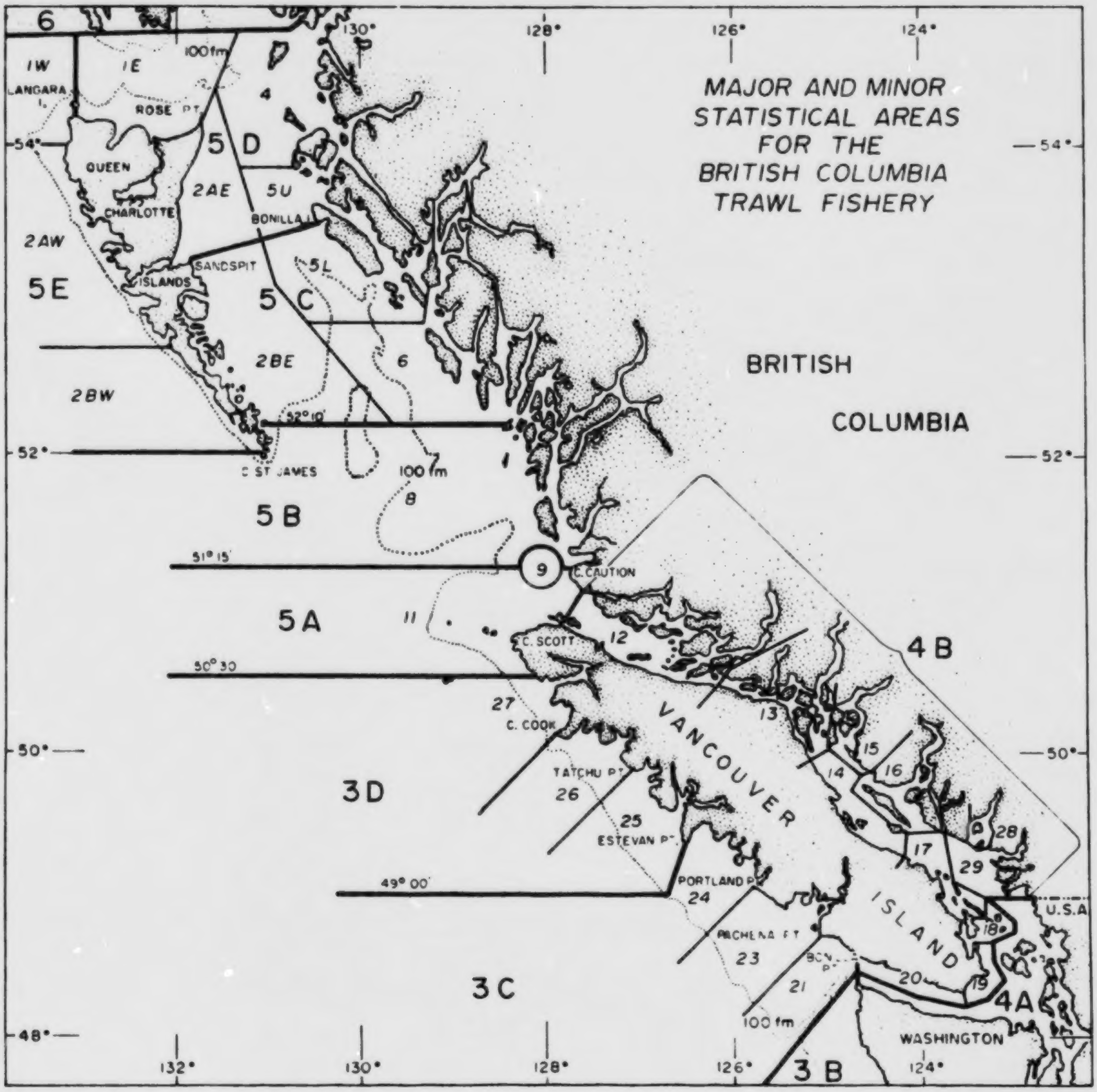

MAJOR AND MINOR
STATISTICAL AREAS
FOR THE
BRITISH COLUMBIA
TRAWL FISHERY
BRITISH
COLUMBIA
VANCOUVER
ISLAND
QUEEN
CHARLOTTE
ISLANDS
WASHINGTON
U.S.A.
6
1W
1E
100fm
LANGARA I.
ROSE PT.
4
5 D
2AE
5U
BONILLA I.
2AW
SANDSPIT
5L
5E
5 C
2BE
6
2BW
52°10'
C. ST JAMES
100 fm
8
5 B
51°15'
9
C. CAUTION
5A
11
C. SCOTT
12
50°30'
4 B
27
C. COOK
13
15
14
16
3D
TATCHU PT.
26
25
ESTEVAN PT.
28
17
29
49°00'
PORTLAND PT.
24
18
PACHENA PT.
23
BON. PT.
21
20
19
4A
3C
100 fm
3 B
132°
130°
128°
126°
124°
54°
52°
50°
48°

Fig. 1.1. International major statistical areas along the British Columbia coast designated by the Groundfish Technical Sub-committee of the Pacific Marine Fisheries Commission.

2.0 LINGCOD

by L. J. Richards and C. M. Hand

2.1 Coastwide

An increase in the size limit from 58 cm to 65 cm is recommended coastwide, to be applied to all gear types. The increase is based on a comparative analysis of size at maturity (Section 2.3.4). A size limit of 65 cm approximates size at 50% maturity for female lingcod. A size limit was initially implemented as a weight limit in 1942 in response to market demands. There is no evidence that size at maturity has changed since 1977, when maturity information began to be routinely collected during biological sampling.

2.2 Strait of Georgia and vicinity (Area 4B)

2.2.1 The Fishery

The commercial lingcod fishery began in the Strait of Georgia in the early 1900s. The maximum reported catch of approximately 3000 t occurred in 1936 (Ketchen et al. 1983). Catch remained high through the 1940s and 1950s, but has declined gradually since the 1960s to the 1988 low of 96 t (Fig. 2.1).

Historically, most of the commercial catch was taken by handline/troll gear, with minor catches by longline and trawl gears (Table 2.1). Fishing activity was concentrated near Campbell River (Statistical Area 13), Pender Harbour (Area 16), and the northern Gulf Islands (Area 17) (Table 2.2). Landings in all areas have declined in recent years to insignificant amounts, with the notable exception of area 12 where landings have increased. These Area 12 landings are probably incidental to the rockfish handline fishery.

The sport angling fishery has been monitored since 1980 by creel and overflight surveys. These surveys provide estimates of the numbers of lingcod caught by anglers by statistical area (Table 2.3). The sport angling catch averaged 121 t annually between 1980-88, with the exception of 1984 when the estimated catch was 220 t. The sport catch has decreased since 1984, to a low of 105 t in 1987 and 1988. However, because of the even greater decline of the commercial fishery, the sport fishery is taking an increasing share of the total lingcod catch. In fact, the sport angling catch has exceeded the comparable commercial handline/troll and longline catch since 1984 (Fig. 2.2). In 1988, the sport fishery accounted for 73% of the total line catch from statistical areas where the sport fishery was monitored.

The sport catch is also recorded from the tidal diary program, combining a sport diary and a visitors survey. Tidal diary estimates of the lingcod sport catch are considerably higher than creel survey estimates (Table 2.3). These higher estimates could be a reflection of the inability of sport fishermen to recall their exact catch at a later time. However, the tidal diary program does include diving and pier fishing which are not included by the creel survey. Based on the tidal diary estimates, the sport fishery accounted for 86% of the total lingcod line catch in 1988 (Fig. 2.2).

Lingcod are also the target of an underwater spear fishery. A survey of the diving community in the Strait of Georgia was conducted in the fall of 1983 to provide estimates of diving effort and collecting activities, including spearfishing (McElderry and Richards 1984). Approximately 50% of the divers surveyed made dives for the purpose of spearfishing. The lingcod spearfishing catch was very roughly estimated at 80 t for 1983, or 65% of the annual sport angling catch.

A winter (Dec.-Feb.) closure to commercial fishing was in effect as early as 1940 (Ketchen et al. 1983) to protect lingcod spawning stocks. In 1979, the existing closure (Dec. 31-Mar. 31) was extended (Nov. 15-Apr. 15) for both commercial and sport fishing. This was an attempt to further protect the pre-spawning aggregation and nest-guarding males, and hence, to improve recruitment. Various measures continued to indicate a decline in lingcod abundance (Richards and Hand 1988). In 1988, the closure period was again extended to April 30. In addition, subareas near Campbell River (13-1 to 13-9, 13-11, and 13-27) were closed to commercial fishing. A size limit of 58 cm is in effect for the commercial fishery coastwide, and there is a bag limit of 3 fish/d for the sport fishery.

2.2.2 Catch Statistics

Catch and effort statistics from sales slip data files have been available from the Department of Fisheries and Oceans (Fisheries Branch, Statistics Unit) since 1967. Catch per unit effort (CPUE), an abundance index, is determined from handline/troll and longline catch and effort data only, since trawl landings have traditionally been unimportant. Historically, most of the commercial handline/troll and longline fishery in Area 4B was targeted on lingcod. Since the late 1970s, however, increased effort has been directed at rockfish. To avoid including directed rockfish effort in the lingcod analysis, CPUE is determined only from sales slip records with a reported lingcod handline/troll or longline catch of at least 100 kg (Richards and Hand 1988). Effort is determined from the ratio of the combined line catch to CPUE.

CPUE for Area 4B lingcod averaged 170 kg/d between 1967-80, and has since declined to the low of 41 kg/d in 1988 (Table 2.4). Decreases in catch, effort, and the number of commercial vessels targeting on lingcod have been coincident with the decrease in CPUE. These factors together are indicative of major decreases in lingcod abundance. The proportion of the total line catch that meets the criterion for inclusion in the CPUE calculation has also decreased, although the 1987-88 values are higher than those in 1985-86. In general, a greater proportion of the lingcod catch is now taken incidentally to other line fisheries such as the inshore rockfish fishery.

Declines in lingcod abundance are also evident from trends in CPUE by Statistical Area. For Area 13, CPUE averaged 269 kg/d between 1967-80 and then declined to the 1988 low of 31 kg/d. The high values of CPUE between 1971-76 were associated with unusually low effort. The values of CPUE for recent years are low in spite of low effort, however. The pattern is similar for Area 17. CPUE remained fairly stable around 158 kg/d between 1967-80, even though effort declined during this period. CPUE, catch and effort have all since declined, although the decline has been less dramatic than in Area 13.

2.2.3 General Biological Information

Biological samples of the commercial handline fishery have been collected sporadically since 1957. Sampling has become increasingly difficult due to the small size of the commercial catch. Samples from Statistical Areas 13 and 17 are available intermittently for 1979-84. Mean size of male and female lingcod decreased over this period in both areas (Table 2.5). In addition, one sample was collected from Area 13 by an observer in 1988. The mean length (63 cm) was considerably smaller than previous samples, and 46% of the total catch was smaller than the size limit. Large fish (>80 cm) were absent from the sample.

The mean sizes presented for the commercial fishery in Table 2.5 may be biased by the degree of compliance with the 58 cm size limit. A different representation of the complete data series is shown in Fig. 2.3, where fish smaller than the size limit have been excluded from calculation of the sample mean. Data for 1985-88 were obtained from research surveys in Area 17 (Cass and Richards 1987, Hand and Richards 1987, Hand et al. 1989). The drop in mean size for 1961, 1964, and 1974 can be accounted for by small sample size (<30 fish), whereas the means for 1982-88 are all based on large samples (>100 fish). The decrease in mean size between 1981-88 cannot be attributed to strong recruitment of small fish, as catch and CPUE have declined concurrently.

The biological sample data from 1957-84, supplemented by the 1985-88 research survey data, may be used in the fishery equilibrium model of Schnute et al. (1989b) to obtain an estimate of annual percentage survival. Due to the structure of these data, the survival estimates apply only to the sizes of fish caught by the commercial fishery. Application of the model requires a knowledge of lingcod growth, and it was assumed that growth rates in Area 4B were similar to those in Area 3C (Schnute et al. 1989a). This assumption appears reasonable for the sample data, following Schnute et al. (1989a). Estimates of survival obtained for different time periods are :

Years	Survival
1957-70	76%
1979-84	79%
1957-84	77%
1985-88	71%
1957-88	76%

Values of percentage survival from 1957-84 are consistent with the values obtained for the Area 3C lingcod stock. Lingcod survival appears to be high over this period for fish in the size range available to the commercial fishery. However, there appears to have been a decrease in survival over the past few years.

Schnute et al. (1989b) also describe graphical and statistical approaches for estimating survival from catch and CPUE, without the biological sample data. From the graphical approach, it is apparent that survival has decreased over the last 5 y, and that recruitment to the commercial fishery is minimal. Mean estimates of survival are 86% for 1967-82 and 68% for 1983-87. An approximate 95% confidence interval for mean survival over the entire time series from the statistical analysis is 67-90%. This range brackets the values from the equilibrium and graphical analyses.

Since 1983, length and sex information for the lingcod sport catch have been collected during the creel survey. Mean fish size has remained fairly constant over the 1983-88 period (Table 2.5). The sport fishery takes a different component of the lingcod stock than the commercial fishery. Most (66%) of the sport-caught fish are smaller than the commercial size limit (Fig. 2.4, Fig. 2.5). Although the equilibrium model of Schnute et al. (1989b) could be applied to the sport data, survival would be underestimated due to gear selectivity. Cass and Richards (1987) and Hand and Richards (1987) compared lingcod catches by sport angling and commercial gear from the same vessel at the same time. They obtained significantly lower values of CPUE and caught significantly smaller fish with angling gear.

Richards et al. (1990) have recently completed an analysis of size at maturity for the offshore lingcod stocks. Following their methodology, size at maturity can be obtained for Area 4B lingcod, based on data from research surveys in 1985-88 (Cass and Richards 1987, Hand and Richards 1987, Hand et al. 1989). There were an insufficient number of immature male lingcod caught during the surveys to estimate size at maturity for males. However, size at 50% maturity for females is 67.4 cm (Table 2.10) with a 95% confidence interval of 65.6-69.2 cm. This is significantly greater than the current commercial size limit of 58 cm, which approximates size at 20% maturity.

A small number of lingcod ovaries were collected during the 1985 research survey (Cass and Richards 1987). Subsamples of oocytes were later counted for each ovary (Richards and Emmett 1988) and fecundity was estimated by the method of Richards and Schnute (1990). Parameter estimates for the relationships between fecundity and length, weight, and age are given in Table 2.6. Fecundity-length and fecundity-age relationships are illustrated in Fig. 2.6.

2.2.4 Condition of the Stock

Lingcod stocks in the Strait of Georgia have continued to decline since the early 1960s. Commercial catch, CPUE, effort, the number of vessels targeting on lingcod, and mean lingcod size have all decreased (Table 2.4), and the rate of decline appears to have accelerated over the last 5 y. In addition, the sport catch has decreased since 1984. Low commercial catches are not a result of poor market conditions as lingcod catches have remained high in other areas of the coast. The lingcod stock is now at an extremely low level of abundance and can no longer support either the sport or the commercial fishery.

Although there is strong evidence that lingcod stocks have declined, the cause of the decline is less clear. Overfishing is suspect, given the large catches during the early part of the commercial fishery and the present large catch of immature fish by the sport fishery. The decline could also be related to changes in lingcod predator abundance, food abundance, or other aspects of habitat quality, poor recruitment associated with small spawning stocks, or any combination of these factors. It is unlikely that research in the near future will be able to establish a cause-effect relationship. Data are available, however, to examine some of these hypotheses.

Although herring are an important food source for lingcod, no relationship is evident between lingcod CPUE and herring abundance, based on either spawning biomass or the escapement model (Haist et al. 1987). Similarly, general climatic conditions do not appear to be a factor in decreasing lingcod abundance as the lingcod decline has been continuous.

Sea mammal predation on lingcod could be significant (P. Olesiuk, DFO, pers. comm.). Since 1970, the harbour seal population has increased at an annual rate of 12.5%. Preliminary data indicate that lingcod account for 1.3-5.5% of the harbour seal diet. This amounts to between 117-492 t of lingcod in 1988.

A preliminary estimate for total sea lion predation in 1988 is 25 t of lingcod, including both the Strait of Georgia and the southern west coast of Vancouver Island. As the increase in the harbour seal population is relatively recent, it is unlikely that they are responsible for the long-term decline in lingcod abundance. However, they are a factor in maintaining the stock at its current low level.

2.2.5 Yield Options

Whatever the cause of the decline, it is apparent that lingcod stocks in the Strait of Georgia cannot sustain current levels of exploitation. As the sport fishery now takes a greater share of the catch, the management strategy must involve both sport and commercial fisheries. Three management options are proposed.

(A) Total closure of the Strait of Georgia (Areas 13-19, 28, 29) to both sport and commercial lingcod fisheries, with no incidental catch permitted. Serious measures are required at this time to prevent further stock collapse. A total lingcod closure was in place in southern Puget Sound between 1978-83. The closure was apparently effective in allowing the stock to recover (G. Bargmann, WDF, pers. comm.). The area is now managed by a 6-wk season and a 1 fish/day bag limit.

(B) Experimental closures of selected statistical areas to both sport and commercial fisheries. For this approach to be effective, approximately half of the Strait of Georgia should be closed. Groups of closed and open areas must be interspersed to allow replication in the experimental design. Closed regions must be sufficiently large to encompass the expected movements of adult lingcod.

(C) A size limit of 65 cm to be applied to both sport and commercial fisheries. The present size limit of 58 cm approximates size at 20% maturity for female lingcod in Area 4B. Size at 50% maturity is approximately 65 cm coastwide (Richards et al. 1990). An increase in the size limit to 65 cm would ensure that a greater number of fish would reproduce at least once. A size limit is a reasonable option for lingcod. Although there have been no studies to examine release mortality, lingcod survival has been high in tagging studies. Further, the survival of lingcod is high for fish above the suggested size limit.

Between 1983-88, 83% of the number and 61% of the biomass caught in the sport fishery were composed of fish less than 65 cm in length. Although a size limit will initially reduce the number of fish caught in the sport fishery, it should increase the yield, or the weight of the catch over the longer term. This would make it possible to promote lingcod as a trophy fish. Effective July 1989, the commercial size limit for lingcod in Alaska is 27 in (69 cm). This limit was imposed due to increased targeting on small fish (Bracken 1989).

2.3 West Coast Vancouver Island (Areas 3C and 3D)

2.3.1 Introduction

Lingcod off the west coast of Vancouver Island are assumed to exist as two discrete stocks or groups of stocks, one off southwest Vancouver Island (Area 3C), and one off northwest Vancouver Island (Area 3D). Analyses and catch statistics are presented by major statistical area. A comprehensive analysis of the population dynamics of lingcod in Area 3C was published in 1989 (Schnute et al. 1989a,b) and the results are updated to 1988 in this assessment. In addition, conclusions are summarized from a comparative analysis of size and age at sexual maturity for Area 3C, 5A and 5B lingcod stocks (Richards et al. 1990).

2.3.2 The Fishery

Lingcod stocks off southwest Vancouver Island are exploited by trawl, hook and line, and recreational fisheries. There have also been undocumented and presumably small catches by Indian food fisheries and foreign national (other than United States) fisheries. The hook and line fishery includes a targeted longline fishery and incidental catches by salmon troll vessels. The commercial trawl fishery accounts for the majority of the lingcod catch. Prior to 1987, there were no legal restrictions on the commercial lingcod catch, except for occasional winter closures and a size limit of 58 cm, implemented initially as a weight limit, in 1942. Lingcod catch has been limited in the past by low market demand. In 1987, a 1400 t quota was placed on the Area 3C lingcod catch, due to concerns over low stock abundance.

2.3.3 Catch Statistics

The compilation of lingcod catch statistics for Area 3C is described in Cass et al. (1988). Briefly, CPUE is calculated from interviewed trawl landings between May-September. A catch is included only if lingcod account for at least 25% of the total catch weight, and the vessel used double gear. Effort recorded for the catch is then standardized for vessel horsepower class (Westrheim and Foucher 1985a, Table 8). In addition, the proportion of the catch that could be accounted for by lingcod above a defined weight of 2.25 kg is determined annually from biological samples. The defined weight was chosen to approximate weight at recruitment to the fishery. CPUE is the ratio of the sum of the qualified catch to the sum of the qualified effort, corrected by the proportion of fish of recruitment weight or greater. Effort is the ratio of total all-gear catch to the corresponding CPUE.

The Area 3C lingcod commercial catch has varied between 500-3600 t (Table 2.7, Fig. 2.7). The 1988 trawl catch is the third lowest on record at 562 t, an increase of 14% from 1987. Line catch (combined handline/troll and longline) has tended to be less variable than trawl catch and has averaged 186 t between 1956-88. The value of 102 t listed for 1988 is a preliminary figure, and the final figure could be as much as 60 t higher (the difference between preliminary and final figures for 1987). However, the major increases in the line catch projected by the trawl fleet have not materialized. Larger line catches were recorded in the 1970s. The 1988 total catch is the second lowest on record at 662 t. CPUE increased in 1988 over the low 1987 value and is comparable to values for the 1976-81 period.

In 1988, the lingcod sport catch in Barkley Sound and Alberni Inlet was monitored by creel survey. The estimated sport catch was 4,372 fish with a mean size of 60 cm (Table 2.5). This amounts to approximately 7 t.

Commercial landing statistics for Area 3D have been compiled in a manner similar to the Area 3C statistics. In years for which there are no Area 3D biological samples, the proportion of fish of recruitment weight or greater in the catch is estimated from the Area 3C samples. CPUE calculated by this method from qualified trawl catch is a less useful abundance index for Area 3D than for Area 3C, because the line catch accounts for a higher proportion of the total Area 3D catch. For example, only 10, 7, and 20% of the total catch met the qualification requirements in 1986, 1987, and 1988, respectively.

The lingcod catch from Area 3D has ranged from 166 t in 1959 to 985 t in 1968 (Table 2.8, Fig. 2.8). The 1988 catch of 518 t, was above the historical average of 406 t. Unlike Area 3C, line catches have increased in Area 3D. Line catches between 1986-88 are the highest on record. CPUE decreased slightly in 1988 to 274 kg/h.

2.3.4 General Biological Information

A comparative analysis of size and age at maturity for the Area 3C and Queen Charlotte Sound (Section 2.4.4) lingcod stocks was completed in 1989 (Richards et al. 1990). Table 2.10 lists estimated lengths at 20, 50, and 80% maturity, and estimated ages for 20, 50, and 80% maturity are listed in Table 2.11. In general, male lingcod mature at a smaller size, but not necessarily a younger age, than do female lingcod. In fact, Richards et al. (1990) found that length and age together provide a better prediction of maturation than do either length or age considered individually. In addition, size and age at maturity increase with latitude for each sex, with the exception of Area 4B (Section 2.2.3). The current commercial size limit of 58 cm falls between length at 20 and 50% maturity for male lingcod, but is smaller than length at 20% maturity for female lingcod. The 95% confidence interval for length at 50% maturity for female Area 3C lingcod is 63.5-64.7 cm.

Schnute et al. (1989b) present a detailed analysis of lingcod survival between 1956-86, based on the time series of catch, CPUE, and biological sample data for the Area 3C commercial fishery. Updating the analysis to include data for 1987-88 results in only minor changes to the survival estimates from their statistical model. The estimate for average annual survival over the 1956-88 period is 75%. The 95% confidence interval for natural mortality is 5-30%, with corresponding estimates of 0-18% for average fishing mortality. Schnute et al. (1989b) noted a possible decline in recruitment over the last 10-15 y, and this decline appears to have continued in 1988.

The updated analyses do not alter any of the conclusions stated by Schnute et al. (1989b). They proposed the "slow-mixing" hypothesis to account for differences in survival estimates they obtained from the statistical fishery model and from an analysis of tag-recapture data. Under this hypothesis, only a small component of the stock is available to the trawl fishery. When fish are removed from the trawl grounds, other fish from nearby rocky areas move into the newly vacated habitat. Survivors from the fishery also move slowly out to rocky areas when space becomes available there. Thus, fish mix slowly between trawlable and non-trawlable habitats. Tests of this hypothesis are planned during the next two years.

Although fewer data are available for Area 3D, parameter estimates obtained from the statistical model are essentially identical to those for Area 3C. The estimate for average annual survival over the 1956-88 period is 76%. The 95% confidence interval for natural mortality is 13-33%, with corresponding estimates of 0-10% for average fishing mortality.

2.3.5 Condition of the Stock

Based on CPUE, Area 3C lingcod stocks are currently at a below-average level of abundance. Similar abundance levels occurred between 1976-81, after which the stock appeared to fully recover. If the "slow-mixing" hypothesis is true, then the lingcod stock will be relatively unaffected by the fishery, unless new methods are found to fish hard-bottom areas or the line fleet increases dramatically and expands into new areas. However, in a worst case scenario, the protected population in rocky areas could be gradually depleted, leading to a sudden, unexpected collapse of the fishery. Stock distribution studies are necessary to test these hypotheses.

2.3.6 Yield Options

It is recommended that a quota on the Area 3C stock be maintained while abundance is low. Yield options for Area 3C and Area 3D were derived from historical catches as follows. Historical catches were divided into two groups, depending on whether they were greater or less than the historical mean of 1400 t. The mean from the first group was chosen as the low-risk sustainable yield, the mean from the second group was chosen as the high-risk sustainable yield, and the historical mean was chosen as the sustainable yield. These options will be re-evaluated after stock distribution studies are complete. Due to the possible decrease in recruitment, it is also recommended that the winter fishing closure (Nov. 15-Apr. 30) be maintained to protect nesting lingcod. In addition, it is recommended that the commercial size limit be increased to 65 cm to more accurately reflect size at maturity for female lingcod. Approximately 22% of lingcod caught by the commercial fishery in Area 3C fall below the proposed size limit.

Yield Option	Area 3C	Area 3D
low risk-sustainable	1000 t	300 t
sustainable	1400 t	400 t
high risk-sustainable	2000 t	600 t

2.4. Queen Charlotte Sound (Areas 5A and 5B)

2.4.1 Introduction

Commercially exploited lingcod stocks are located on the Cape Scott (Area 5A) and Goose Island (Area 5B) grounds. As few commercial samples are available for Area 5A lingcod, and as catch trends are similar in both areas, lingcod in Queen Charlotte Sound are treated as one stock for this assessment. The assessment is based on the analysis described in Schnute et al. (1989a,b) for the Area 3C lingcod stock.

2.4.2 The Fishery

Lingcod stocks in Queen Charlotte Sound are primarily exploited by commercial trawl vessels. There are also small catches by hook and line vessels. Lingcod have generally been a relatively minor component of the Queen Charlotte Sound trawl fishery.

2.4.3 Catch Statistics

The compilation of catch statistics for Area 5A/B is similar to that discussed for Area 3C (section 2.3.3). CPUE for Area 5A and 5B is calculated from 25% qualified interviewed trawl catch between May-September. Qualified effort is standardized for vessel horsepower class (Westrheim and Foucher 1985a, Table 8). CPUE for Area 5A/5B combined is also corrected for a weight at recruitment to the fishery of 2.25 kg, based on the average weight-frequency distribution of the 1956-87 commercial samples (Richards and Hand 1988). Effort is calculated from the ratio of catch to CPUE.

Catch from Area 5A and Area 5B contributed about equally to the Area 5A/B total between 1956-70 (Table 2.9, Fig. 2.9). Since 1970, with the exception of 1987, catch has been greater from Area 5B. In general, trends in trawl catch and CPUE have remained similar in the two areas. However, the line catch has been increasing in Area 5A. The 1988 combined catch of 1397 t and the CPUE of 263 kg/h are above average for the 1956-88 period.

2.4.4 General Biological Information

As discussed in Section 2.3.4, an analysis of size and age at maturity was completed for the Queen Charlotte Sound stocks (Richards et al. 1990). Male lingcod mature at a significantly ($p<0.05$) smaller size than do female lingcod (Table 2.10). In addition, male lingcod from Area 5A and 5B mature at a larger size than do male lingcod from Area 3C. Similarly, female lingcod from Area 5B mature at a larger size than do female lingcod from Area 3C and 5A. Confidence intervals (95%) for size at 50% maturity are 64.4-66.6 cm and 66.0-67.0 cm for female lingcod from Area 5A and 5B, respectively.

Estimates of average annual survival may be obtained for the Area 5A/B stock as described in Schnute et al. (1989b), using the growth estimates derived for the 1988 assessment (Richards and Hand 1989). The estimate for total survival is 87% (95% confidence interval of 77-87%) with a natural mortality of 13% and a fishing mortality of 6%. The 95% confidence interval for natural mortality is 1-21% with a corresponding fishing mortality of 0-15%. None of these estimates differ significantly from the corresponding estimates for the Area 3C stock.

2.4.5 Condition of the Stock

Estimates of survival and mortality are similar for Area 3C and Area 5A/B stocks. Hence, similar conclusions apply to lingcod stocks in the two areas. Stocks in Area 5A/B are probably sustainable at current rates of exploitation, and they appear to be at above-average levels of abundance.

2.4.6 Yield options

An increase in the commercial size limit to 65 cm is recommended coastwide. Yield options are derived from historical catches as discussed in Section 2.3.6. The low-risk sustainable yield is 600 t, the sustainable yield is 900 t and the high-risk sustainable yield is 1400 t.

Table 2.1. Lingcod handline/troll catch (t), longline catch (t), trawl catch (t), and total catch (t) for Area 4B, 1951-88.

Year	Handline/troll[a]	Longline[a]	Trawl[b]	Total
1951	1279.5	27.4	48.1	1355.0
1952	1488.8	17.2	54.0	1560.0
1953	1179.2	6.3	28.1	1213.6
1954	1449.4	9.4	69.2	1528.3
1955	1220.1	8.5	50.6	1279.2
1956	1512.1	9.6	55.7	1577.4
1957	1539.7	4.5	42.0	1586.2
1958	1445.6	4.0	74.6	1524.2
1959	1183.0	6.7	336.4	1526.1
1960	1250.6	21.4	184.1	1456.1
1961	1157.7	30.7	102.1	1290.5
1962	1272.8	14.3	75.7	1362.9
1963	989.3	9.3	39.7	1038.3
1964	870.4	5.5	90.3	966.2
1965	779.7	6.5	93.8	880.0
1966	771.3	20.0	56.0	847.3
1967	781.0	14.5	54.4	849.9
1968	729.8	12.5	94.6	836.9
1969	747.9	19.9	65.6	833.4
1970	792.0	31.3	48.8	872.1
1971	564.9	34.3	60.5	659.7
1972	513.4	10.3	34.7	558.4
1973	373.1	31.2	15.0	419.3
1974	354.7	16.2	49.4	420.3
1975	331.4	37.3	33.9	402.6
1976	316.0	15.3	43.6	374.9
1977	408.7	24.9	32.1	465.7
1978	445.2	56.5	42.7	544.4
1979	505.5	56.0	26.6	588.1
1980	342.1	12.0	38.2	392.3
1981	334.5	9.2	67.1	410.8
1982	358.8	11.4	196.6	566.8
1983	274.7	12.6	135.4	422.7
1984	182.7	10.4	90.6	283.7
1985	129.2	8.6	34.0	171.8
1986	99.1	16.1	44.5	159.7
1987	71.3	9.2	17.2	97.7
1988	76.3	7.2	12.4	95.9

[a] British Columbia Catch Statistics, Annual Reports.
[b] Groundfish data files.

Table 2.2. Lingcod handline/troll and longline catch (t) for Area 4B by Statistical Area, 1951-88.

	Statistical Area										
Year	12	13	14	15	16	17	18	19	20	28	29	Total
1951	23.3	397.9	88.5	46.3	99.3	357.9	253.2	32.2	17.3	1.8	0.4	1318.1
1952	11.8	440.3	83.6	73.2	169.3	438.0	235.7	28.6	25.2	7.0	0.0	1512.7
1953	5.7	345.8	84.4	46.1	166.2	289.0	179.0	38.9	28.2	4.4	0.1	1187.8
1954	16.0	437.3	157.6	21.5	244.9	362.5	169.1	33.7	13.2	4.8	1.9	1462.5
1955	6.5	330.0	84.4	64.7	243.0	338.9	112.3	44.1	8.0	0.0	0.0	1231.9
1956	17.2	564.7	96.3	60.6	235.0	396.8	106.9	44.1	2.1	1.2	0.8	1512.3
1957	7.0	542.4	82.4	107.2	288.4	364.7	96.9	54.0	2.3	0.3	0.8	1546.4
1958	16.5	497.2	105.6	79.3	229.7	350.2	93.5	73.8	4.5	0.6	0.0	1450.9
1959	16.1	338.3	86.7	31.4	167.8	345.3	85.3	104.7	0.8	0.6	15.4	1192.4
1960	24.3	337.9	110.7	47.1	173.9	378.0	97.0	82.8	23.1	1.3	3.5	1279.6
1961	32.1	393.1	92.1	45.6	183.7	285.7	64.3	63.6	29.6	7.7	2.4	1199.9
1962	160.2	412.0	114.1	60.4	139.0	241.2	57.2	76.4	19.4	8.9	4.1	1293.0
1963	68.0	301.4	63.1	30.5	159.6	250.6	44.7	63.5	20.7	0.1	0.1	1002.3
1964	36.3	289.8	43.3	18.8	170.0	191.5	53.8	52.6	21.4	0.1	0.4	878.0
1965	30.3	303.2	52.4	6.6	135.8	155.3	50.1	39.3	11.2	0.0	4.6	788.8
1966	44.4	299.5	61.7	28.7	125.7	131.4	61.2	33.0	17.6	1.1	0.0	804.3
1967	49.3	332.8	55.7	19.8	133.3	109.6	69.9	17.8	7.0	0.0	0.4	795.6
1968	50.7	273.6	54.2	22.0	104.7	157.7	53.3	14.8	10.5	0.0	0.7	769.2
1969	61.9	227.7	81.9	56.0	109.5	143.5	52.3	31.7	13.8	0.0	0.1	778.4
1970	46.4	225.5	40.8	84.7	85.7	272.1	37.4	23.7	6.5	0.0	0.6	823.4
1971	50.1	119.2	30.0	66.5	89.7	199.9	22.7	18.9	2.2	0.1	0.1	599.4
1972	39.5	152.3	25.1	43.6	81.3	129.9	19.6	38.5	2.4	0.0	0.5	532.7
1973	22.2	85.9	8.4	62.0	38.2	123.7	34.4	27.7	1.1	0.6	0.2	404.4
1974	11.2	129.6	13.3	25.2	23.3	127.6	22.2	16.7	2.9	0.0	0.3	372.3
1975	8.6	93.9	15.1	76.0	26.5	123.0	10.9	8.9	5.0	0.0	0.9	368.8
1976	10.4	96.0	12.9	74.9	17.2	82.5	13.4	9.8	7.8	5.7	0.4	331.0
1977	25.7	128.0	31.4	63.4	19.0	104.1	40.6	15.7	2.6	2.2	0.3	433.0
1978	13.8	158.0	25.3	48.3	18.4	145.3	36.1	42.2	5.7	0.2	2.0	495.3
1979	29.2	215.5	36.8	28.7	15.6	157.4	26.9	30.2	13.7	7.1	1.5	562.6
1980	14.7	131.6	14.2	25.8	6.6	103.3	23.9	23.0	5.3	4.5	0.7	353.3
1981	17.5	137.4	28.9	34.6	12.9	83.6	16.4	16.3	3.3	0.1	0.5	351.5
1982	20.1	177.8	14.9	48.0	7.7	59.6	20.3	17.5	2.1	0.5	1.1	369.6
1983	16.8	112.3	17.9	32.9	13.2	56.5	18.0	14.1	4.6	0.3	0.3	286.9
1984	18.7	65.6	7.0	4.0	5.2	46.5	30.1	13.0	2.5	0.0	0.2	192.8
1985	20.1	46.0	8.2	4.0	0.3	29.8	15.9	10.5	2.6	0.0	0.3	137.7
1986	21.0	20.2	16.0	0.5	2.4	17.2	12.9	13.7	1.8	0.0	0.5	106.2
1987	15.6	22.6	2.2	0.9	0.1	10.0	8.0	8.4	5.9	6.7	0.0	80.4
1988	43.6	12.1	2.5	0.1	0.2	7.1	4.4	8.4	2.4	1.6	1.1	83.5

Source: 1951-1966 British Columbia Catch Statistics, Annual Reports.
1967-88: Sales slip data files.

Table 2.3. Lingcod sport catch (t)[a] for the Strait of Georgia by Statistical Area from the creel survey (Shardlow and Hoyt, unpub. data), and the total for the same areas from the sport diary and visitors surveys (Bijsterveld, unpub. data), 1980-1988.

	Statistical Area										
Year	13	14	15	16	17	18	19	28	29	Creel Total	Tidal Diary Total
1980	41.8	12.6	2.4	22.6	12.6	9.6	13.8	4.6	6.7	126.7	179.4[b]
1981	43.4	17.1	8.0	15.4	9.1	12.6	23.0	7.4	9.8	145.8	170.2[b]
1982	24.0	9.1	2.1	31.4	14.2	9.6	20.3	9.8	5.9	126.4	210.9[b]
1983	25.8	3.7	1.8	32.2	11.4	10.1	15.7	10.9	6.9	118.3	193.3
1984	63.5	18.2	2.7	45.9	26.2	11.4	26.4	14.2	13.0	219.8	303.0
1985	37.1	9.9	1.4	22.4	14.2	4.5	20.8	5.0	4.3	123.7	311.8[c]
1986	41.3	15.5	2.1	15.0	10.1	6.9	17.1	3.0	2.6	113.6	344.8
1987	37.6	16.5	2.3	13.0	11.1	4.8	17.5	1.3	1.2	105.3	277.1
1988	36.1	18.5	2.1	15.7	9.3	5.6	14.4	1.2	2.7	105.5	241.6[d]

[a] An average weight of 1.6 kg was used to convert numbers to weight.
[b] Sport diary component only, no visitors survey available.
[c] Sport diary component estimated as the mean of 1984 and 1986 totals.
[d] Visitor component estimated as the mean of 1983-1987.

Table 2.4. Lingcod CPUE (kg/d) by Statistical Area and for Area 4B combined, lingcod catch (t) by handline/troll and longline for Area 4B, the proportion (prop.) of the catch by these gears that satisfies the qualification criterion, effort (d), and the number of vessels (vess.) that reported a qualified line catch.

	CPUE by Statistical Area														
Year	12	13	14	15	16	17	18	19	20	28/29	CPUE	Catch	Prop.	Effort	Vess.
1967	53	301	236	314	213	127	124	164	130	87	181.1	795.5	0.86	4313	
1968	37	318	179	375	194	127	110	168	157	227	156.8	742.3	0.89	4734	
1969	57	272	168	438	213	136	129	292	128	-	170.3	767.8	0.89	4509	
1970	50	254	168	351	196	175	154	228	161	257	182.0	823.3	0.90	4524	
1971	83	266	171	267	196	166	113	217	275	25	174.2	599.2	0.89	3440	
1972	50	301	201	283	178	143	150	191	245	147	164.9	523.7	0.85	3176	
1973	40	287	132	264	185	167	150	207	191	119	168.4	404.2	0.91	2401	
1974	36	312	253	269	135	139	135	170	156	327	172.1	370.9	0.90	2155	
1975	23	312	160	242	194	171	189	193	208	46	189.5	368.7	0.94	1966	
1976	38	275	150	250	123	174	126	128	168	140	181.2	331.3	0.89	1825	
1977	52	200	192	256	222	148	125	136	45	115	155.9	433.6	0.76	2781	
1978	74	192	126	206	278	155	105	131	33	210	150.8	501.8	0.88	3327	
1979	76	198	144	270	184	224	116	124	144	163	173.8	561.5	0.85	3231	253
1980	73	274	87	220	92	167	95	101	105	119	159.7	354.1	0.85	2217	205
1981	168	177	90	194	129	148	87	94	77	46	146.1	343.7	0.87	2352	206
1982	66	189	85	152	83	129	130	96	100	55	139.8	370.2	0.86	2648	226
1983	123	138	118	235	127	144	95	93	194	51	138.3	287.3	0.85	2077	174
1984	76	74	80	99	126	95	159	124	100	36	91.6	193.1	0.83	2108	156
1985	74	107	90	104	156	132	71	191	36	96	100.3	137.8	0.70	1374	96
1986	45	53	131	175	119	103	87	114	78	35	73.8	106.2	0.60	1439	83
1987	33	32	44	93	-	84	87	53	141	213	50.4	80.5	0.75	1596	89
1988	37	31	19	-	-	84	84	59	50	96	40.7	83.5	0.77	2052	73

Table 2.5. Mean length (cm) of lingcod, with sample size (N) and standard error (SE), from biological samples of the commercial handline and sport fisheries by Statistical Area and sex. The 1988 commercial sample is given for the total catch and for the kept catch (in compliance with the 58 cm limit).

	Male			Female			Combined sexes		
Year	N	Mean	SE	N	Mean	SE	N	Mean	SE
Commercial Fishery - Area 13									
1981	72	71.0	0.7	244	76.0	0.6	316	74.8	0.5
1982	54	71.0	0.7	173	80.7	0.7	227	78.4	0.6
1983	137	70.3	0.5	527	80.2	0.4	667	78.1	0.4
1984	124	66.2	0.6	131	73.8	0.8	255	70.1	0.5
1988-total	93	55.9	0.6	71	61.1	0.9	164	58.2	0.5
1988-kept	43	60.6	0.5	46	65.5	0.7	89	63.1	0.5
Commercial Fishery - Area 17									
1979	70	70.8	0.9	130	81.1	1.0	200	77.5	0.8
1981	360	69.6	0.4	271	81.6	0.8	633	74.5	0.5
1982	90	68.9	0.8	135	81.6	0.8	255	76.5	0.7
1983	591	65.9	0.3	614	73.2	0.4	1207	69.5	0.3
Sport Fishery - Strait of Georgia									
1983	13	53.4	2.0	14	57.2	3.6	27	55.4	2.1
1984	24	59.2	1.8	16	61.7	3.4	41	59.8	1.7
1985	129	53.5	0.7	89	54.5	1.2	219	53.9	0.7
1986	351	53.9	0.5	179	59.1	1.0	545	55.5	0.5
1987	318	55.3	0.6	212	56.8	1.0	543	55.8	0.5
1988	170	55.4	0.8	139	60.3	1.1	320	57.5	0.7
Sport Fishery - Barkley Sound									
1988	59	59.4	9.9	2	64.2	17.5	83	60.1	8.5

Table 2.6. Parameter estimates for the relationship between lingcod fecundity (10^3 oocytes) and length (cm), weight (g) and age (y), and the sample size (N). The analysis uses the constants (v,V)=(50,200) representing typical low and high values of fecundity (with units of 10^3 cm) as well as the constants (u,U) representing typical low and high values, respectively, of the x-variate. These constants are fixed prior to the analysis. The parameters b and c represent exponents on x and y, respectively, and p and q represent the intercept and slope of a linear relationship between non-linear transforms of x and y. For a complete description of the model see Richards and Schnute (1990).

x-variate	N	u	U	b	c	p	q
length	39	60	100	-0.78	-4.70	-0.18	1.01
weight	39	2000	15000	-0.51	-0.68	-0.13	1.17
age	37	4	10	0.08	-0.63	0.18	0.54

Table 2.7. Lingcod trawl catch, line catch, total catch, CPUE and effort for Area 3C, 1956-88.

Year	Trawl (t)	Line (t)	Total (t)	CPUE (kg/h)	Effort (h)
1956	1151	156	1307	292	4398
1957	1070	295	1365	307	4405
1958	1047	156	1203	442	2580
1959	1742	113	1855	408	4266
1960	1867	219	2086	293	6634
1961	1972	136	2108	426	4555
1962	890	228	1118	291	3676
1963	609	147	756	462	1608
1964	1127	101	1228	437	2737
1965	1812	122	1934	398	4476
1966	2030	158	2188	329	6189
1967	1779	246	2025	408	4716
1968	1661	156	1817	584	2786
1969	1054	171	1225	298	3673
1970	703	286	989	291	3302
1971	979	231	1210	346	3469
1972	625	267	892	278	3139
1973	876	185	1061	364	2836
1974	1029	224	1253	240	4933
1975	1630	216	1846	292	5555
1976	1205	253	1458	204	6956
1977	844	267	1111	236	4618
1978	360	91	451	184	2404
1979	602	82	684	220	3044
1980	623	97	720	242	2876
1981	603	240	843	179	3870
1982	1510	221	1731	331	4917
1983	970	170	1140	314	3507
1984	1731	128	1859	391	4581
1985	3416	207	3623	469	7364
1986	834	241	1075	325	3127
1987	492	234	726	189	3504
1988	562	102	662	231	2707

Table 2.8. Lingcod trawl catch, line catch, total catch, CPUE and effort for Area 3D, 1956-88.

Year	Trawl (t)	Line (t)	Total (t)	CPUE (kg/h)	Effort (h)
1956	168	135	303	421	707
1957	130	146	276	588	470
1958	109	130	239	723	314
1959	64	102	166	563	276
1960	87	115	202	776	244
1961	200	125	325	591	550
1962	286	112	398	298	1334
1963	115	132	247	365	664
1964	226	92	318	540	578
1965	505	97	602	404	1457
1966	585	147	732	607	1177
1967	459	180	639	566	1098
1968	868	117	985	681	1400
1969	619	84	703	306	2053
1970	456	171	627	321	1922
1971	264	124	388	246	1548
1972	85	197	282	235	1168
1973	172	91	263	411	630
1974	242	123	365	509	677
1975	347	97	444	251	1553
1976	245	98	343	302	1108
1977	158	116	274	293	922
1978	197	95	292	458	625
1979	147	110	257	316	809
1980	127	95	222	199	1074
1981	87	122	209	170	1014
1982	49	175	224	188	1119
1983	447	153	600	299	1944
1984	322	153	475	204	2241
1985	380	194	574	478	1199
1986	246	229	475	306	1458
1987	88	327	415	288	1317
1988	282	236	518	274	1843

Table 2.9. Lingcod trawl catch, line catch, total catch, CPUE and effort for Area 5A and Area 5B, and Area 5A/B catch, CPUE and effort, 1956-88.

	Area 5A				Area 5B				Area 5A/B		
Year	Trawl (t)	Line (t)	Tot. (t)	CPUE (kg/h)	Trawl (t)	Line (t)	Tot. (t)	CPUE (kg/h)	Total (t)	CPUE (kg/h)	Effort (h)
1956	350	24	374	371	250	4	254	470	628	443	1416
1957	433	1	434	258	170	6	176	295	611	284	2135
1958	296	1	297	139	276	0	276	417	573	353	1613
1959	192	1	193	359	429	1	430	410	623	400	1544
1960	280	13	293	276	377	2	379	373	673	352	1903
1961	388	19	407	534	323	3	326	274	733	366	1964
1962	531	36	567	363	407	5	412	297	979	328	2940
1963	285	27	312	295	357	16	373	259	685	280	2423
1964	352	8	360	342	335	8	343	186	703	305	2272
1965	331	5	336	363	566	8	574	169	910	282	3148
1966	706	24	730	349	826	7	833	362	1563	351	4423
1967	759	22	781	322	901	5	906	477	1687	368	4543
1968	1227	17	1244	296	1043	11	1054	400	2298	302	7214
1969	617	28	645	139	517	9	526	233	1170	156	7290
1970	590	29	619	250	390	16	406	255	1026	248	4093
1971	230	27	257	141	415	14	429	174	685	156	4351
1972	164	47	211	197	476	27	503	157	714	173	4119
1973	232	38	270	178	349	20	369	131	639	173	3689
1974	339	40	379	203	532	31	563	205	942	202	4637
1975	82	31	113	112	451	23	474	203	587	161	3629
1976	258	42	300	244	345	28	373	174	673	194	3467
1977	122	50	172	117	257	18	275	195	446	157	2838
1978	128	20	148	224	162	12	174	168	322	189	1692
1979	100	32	132	186	242	12	254	179	386	167	2137
1980	108	33	141	103	302	12	314	174	455	137	2842
1981	183	33	216	227	548	12	560	237	776	216	3304
1982	468	35	503	249	580	9	589	239	1091	236	4492
1983	573	37	610	267	772	10	782	337	1392	307	4501
1984	261	47	308	190	455	10	465	198	773	187	3966
1985	408	45	453	255	469	23	492	236	944	227	3874
1986	640	41	681	346	1012	7	1019	403	1700	367	4468
1987	676	99	775	267	756	10	766	330	1541	289	5233
1988	554	99	653	285	736	8	744	359	1397	307	4298

Table 2.10. Estimates of length (cm) at 20, 50, and 80% maturity and corresponding estimates of the shape parameter c with fixed b=1 for male (M) and female (F) lingcod from areas 4B, 3C, 5A, and 5B. Model details and values of the fixed parameters are described in Richards et al. (1990).

				Length at % maturity		
Sex	Area	b	c	20%	50%	80%
M	3C	1	5.49	51.3	58.1	62.5
M	5A	1	2.13	57.0	60.8	64.4
M	5B	1	0.10	58.7	62.2	65.8
F	4B	1	3.60	57.6	67.4	74.5
F	3C	1	-0.28	60.0	64.1	68.6
F	5A	1	2.79	59.9	65.5	70.3
F	5B	1	-1.86	63.4	66.5	70.1

Table 2.11. Estimates of age (y) at 20, 50, and 80% maturity and corresponding estimates of the shape parameter c with fixed b for male (M) and female (F) lingcod from areas 3C and 5B. Model details and values of the fixed parameters are described in Richards et al. (1990).

				Age at % maturity		
Sex	Area	b	c	20%	50%	80%
F	3C	-1	1.68	3.3	3.9	4.8
F	5B	-1	1.79	3.7	4.3	5.4
M	3C	1	1.04	2.4	3.5	4.5
M	5B	1	-0.82	4.4	5.0	5.9

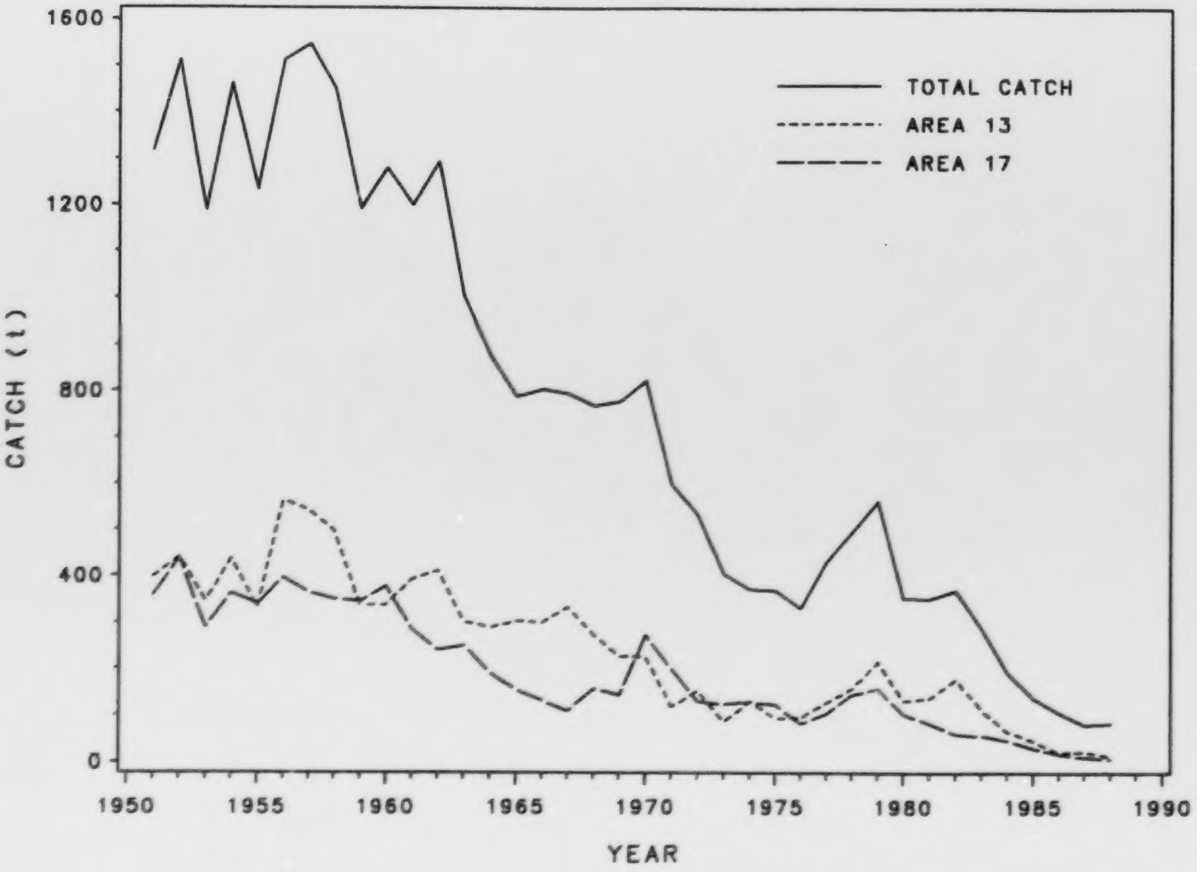


Fig. 2.1. Nominal lingcod handline/troll and longline catch from Area 4B combined, and from statistical areas 13 and 17, 1951-1938.

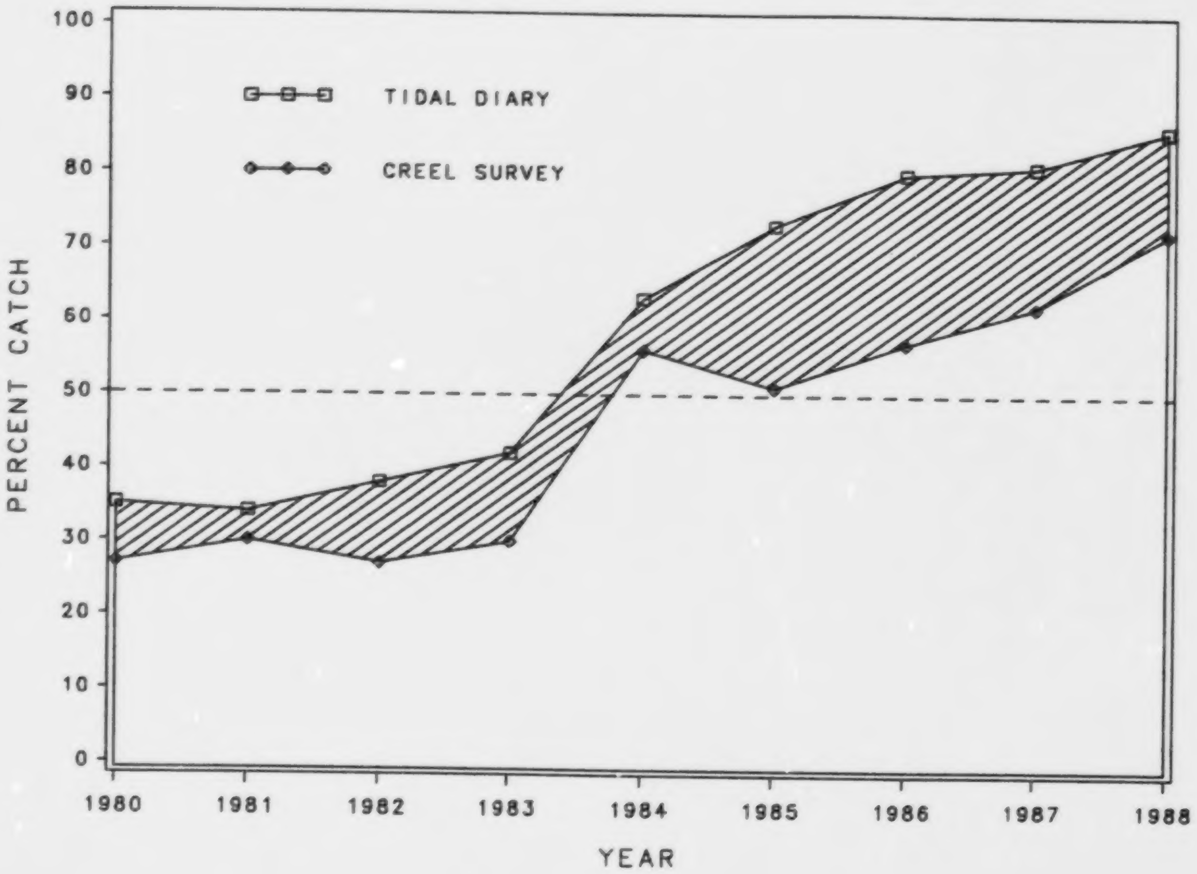


Fig. 2.2. Percent of the total lingcod line catch caught by the sport fishery in statistical areas 13-19, 28 and 29 between 1980-88, based on the creel survey and the tidal diary program. The shaded area represents the range between the two estimates.

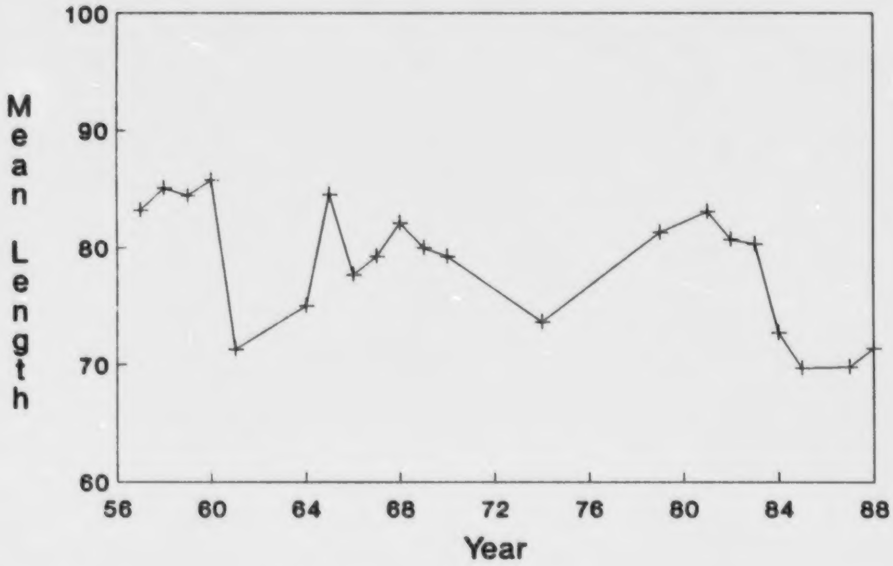


Fig. 2.3. Mean length (cm) of lingcod sampled from the Strait of Georgia commercial fishery between 1957-84 and from 1985-88 research surveys in area 17. Fish smaller than the commercial size limit (58 cm) have been excluded from the mean calculations.

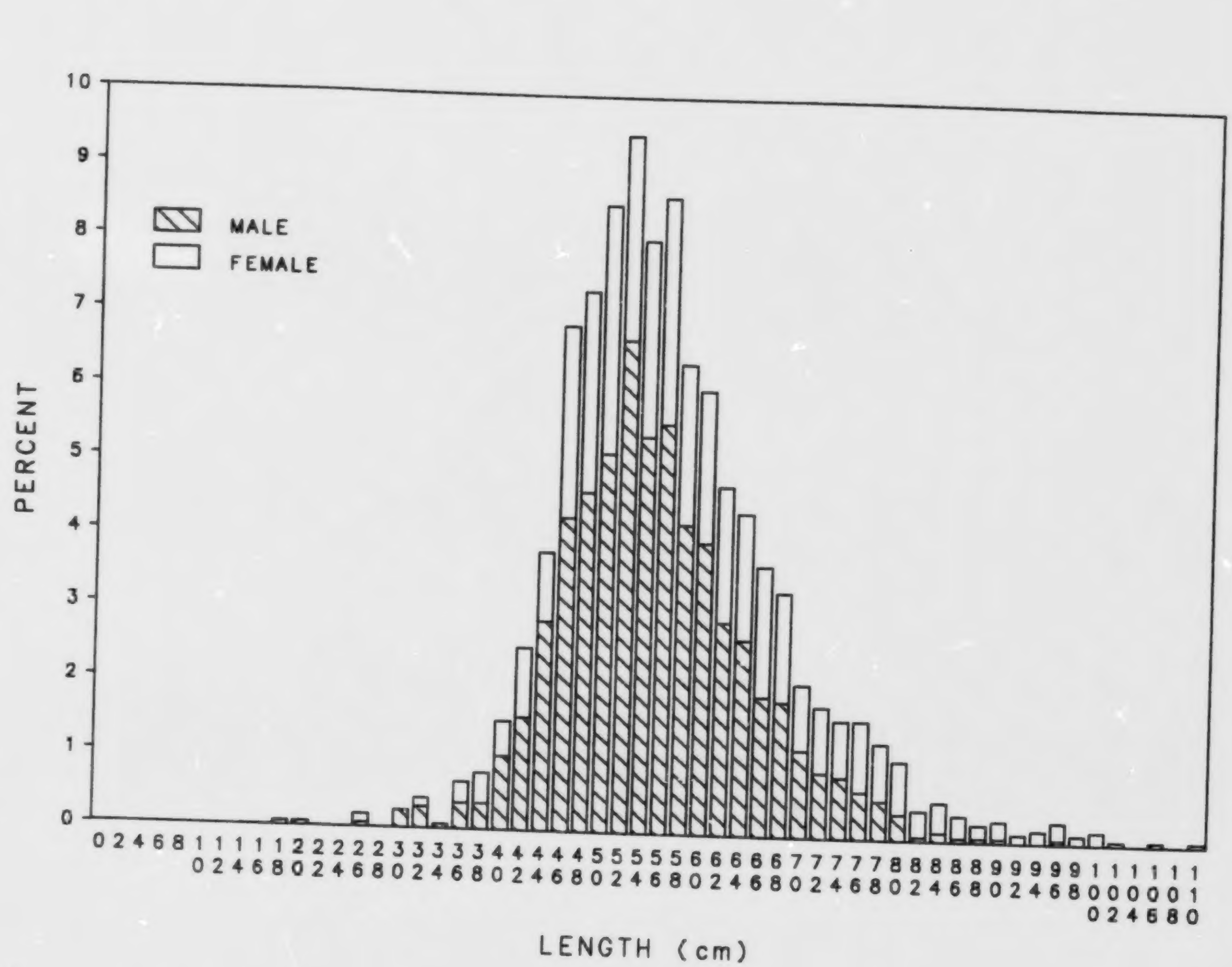


Fig. 2.4. Length-frequency distribution of lingcod caught in the sport fishery, 1933-88 (N=1692).

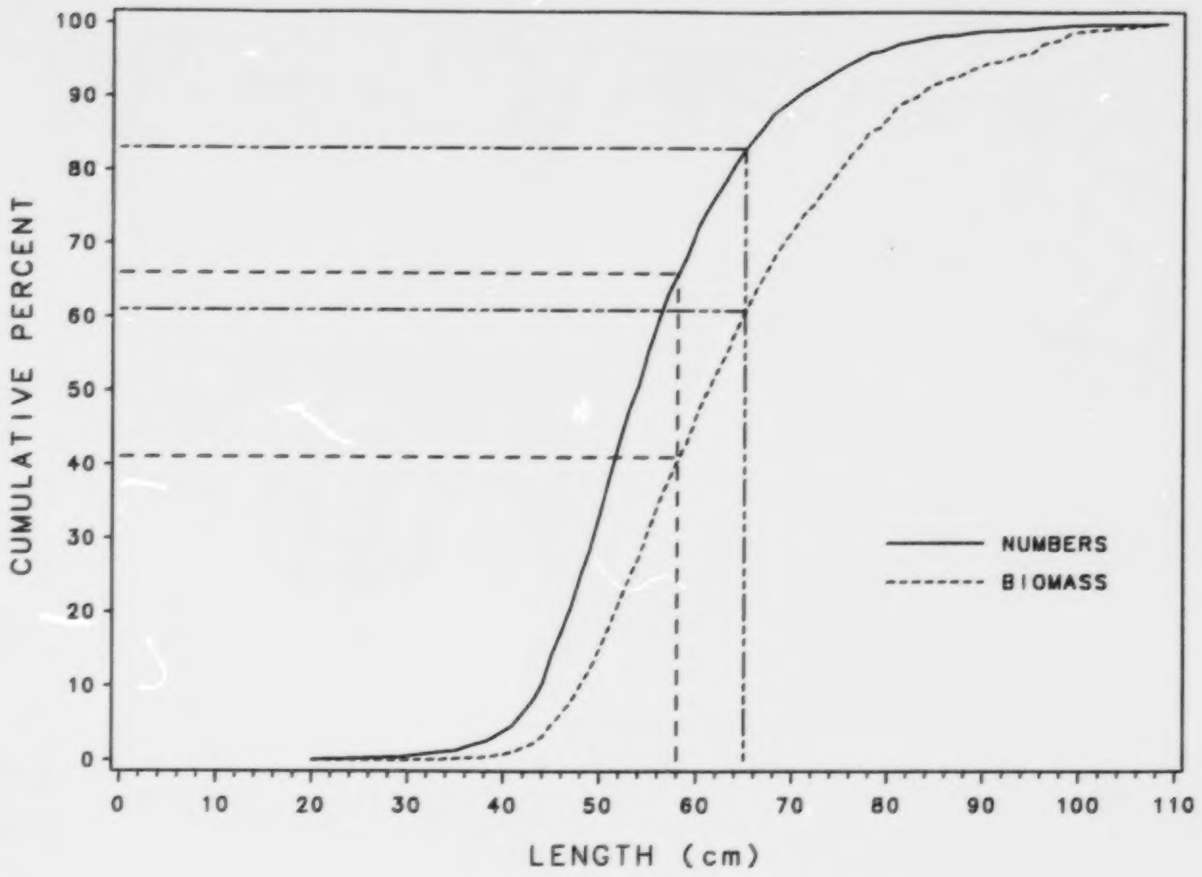


Fig. 2.5. Cumulative length-frequency distributions by number and biomass for lingcod caught in the sport fishery, 1933-88 (N=1735). The dashed lines indicate the proportions of the catch by number and biomass less than the current commercial size limit of 58 cm. The variable dashed lines indicate the corresponding proportions for a 65 cm size limit.

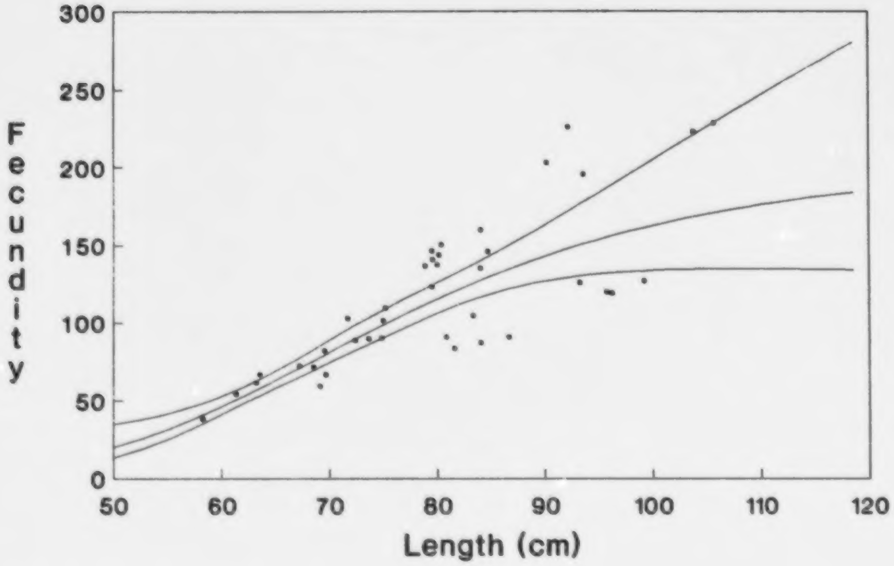


Fig. 2.6a. Observed data points and the predicted curve with 95% confidence intervals for the relationship between fecundity (10^3 oocytes) and length (cm) for lingcod from area 17. Parameter values are given in Table 2.6.

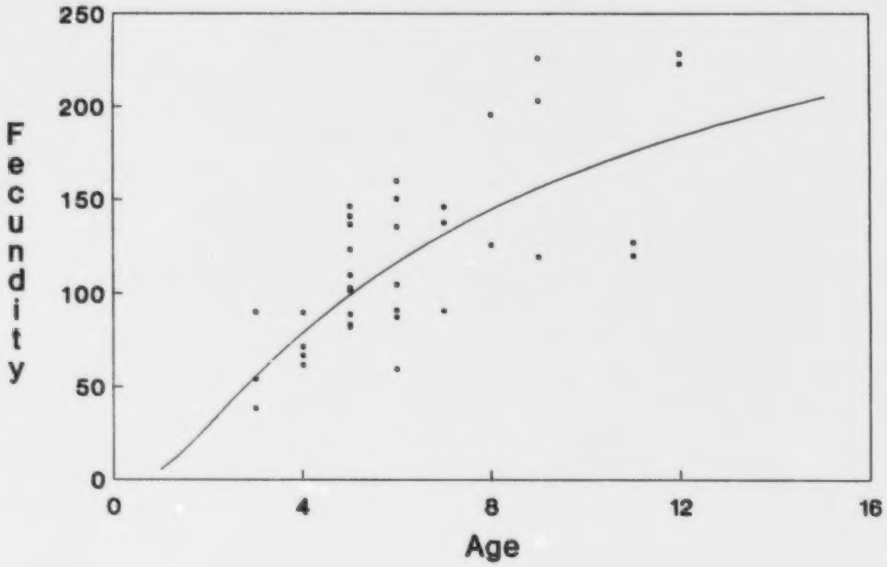


Fig. 2.6b. Observed data points and the predicted curve for the relationship between fecundity (10^3 oocytes) and age (y) for lingcod from area 17. Parameter values are given in Table 2.6.

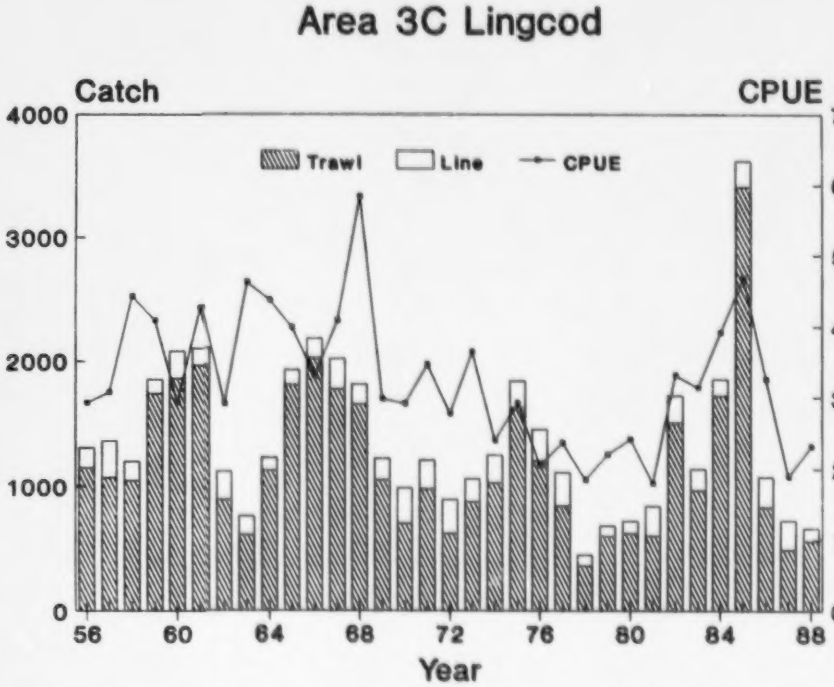


Fig. 2.7. Nominal lingcod trawl catch (t, filled bars), line catch (t, stacked open bars), and CPUE (kg/h, line) for Area 3C, 1956-88.

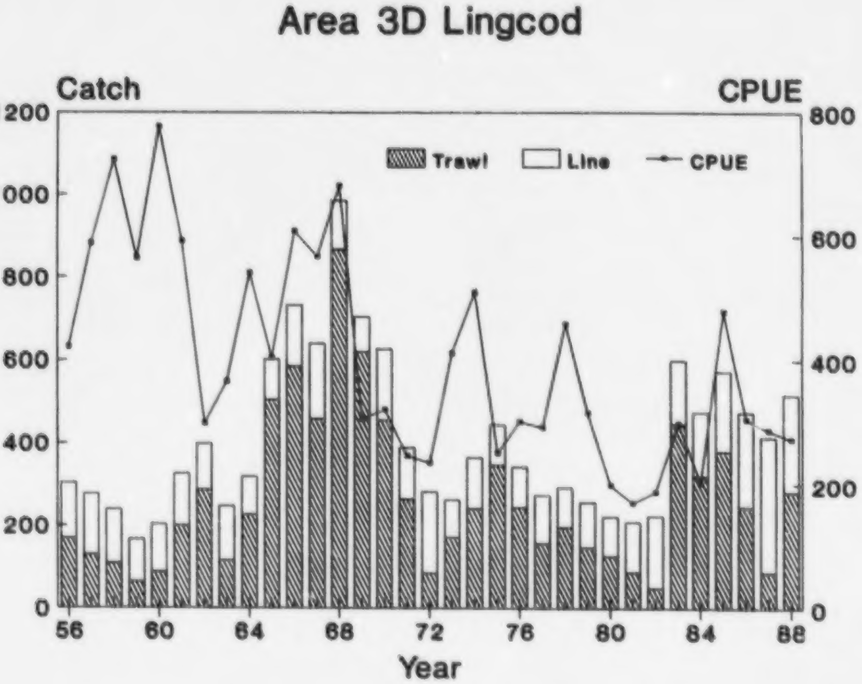


Fig. 2.8. Nominal lingcod trawl catch (t, filled bars), line catch (t, stacked open bars), and CPUE (kg/h, line) for Area 3D, 1956-88.

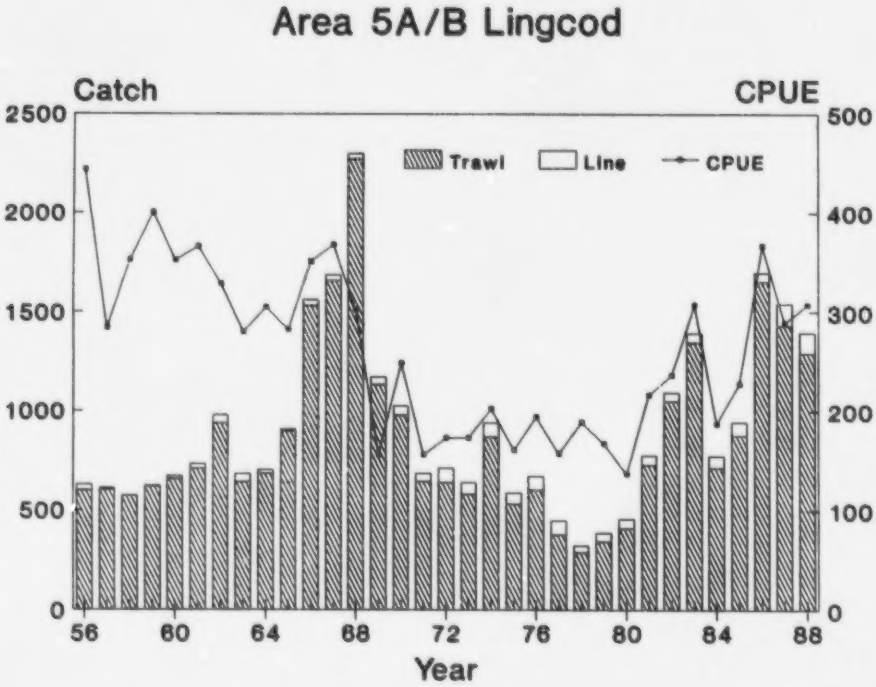


Fig. 2.9. Nominal lingcod trawl catch (t, filled bars), line catch (t, stacked open bars), and CPUE (kg/h, line) for Area 5A/B, 1956-88.

3.0. PACIFIC COD

by A. V. Tyler and R. P. Foucher

3.0.1. General Introduction

Pacific cod (Gadus macrocephalus) continues to be a major component of the domestic, on-bottom trawl fishery. The 11,070 t of Pacific cod landed in 1988 was exceeded only by the landings of Pacific hake at 56,576 t. The landed value of $5.65 million for Pacific cod ranked third after sablefish ($17.95 million) and Pacific hake ($8.8 million). In Canadian waters, Pacific cod is close to the southern limit of its commercial abundance and exhibits rapid growth and a short life span. Recruitment begins at age 2, while most are recruited and mature at age 3. Few survive to age 7. Year-class strength varies considerably resulting in a wide variation in annual landings (Fig. 3.1).

Among regions, cod production is greatest in the most northerly Canadian stock, Hecate Strait, and negligible off the west coast of the Queen Charlotte Islands. Cod production continues to be high due to the presence of the strong 1985 year-class, and in spite of the presently poor market conditions.

3.1. Coastwide

Pacific cod were not treated as a coastwide stock.

3.2. Georgia Strait and vicinity (Area 4B)

3.2.1. Introduction

No new analyses have been conducted since a detailed stock assessment was carried out in 1986 (Westrheim and Foucher 1987). Nominal catch (landings) during 1988 were 1220 t, an increase of 20% over 1987 (Table 3.1). Landings during January-June 1989 were 240 t, down 50% over the same period in 1988.

3.2.2. Landing Statistics

Landings were compiled and reported by calendar year. Equivalent effort was calculated by dividing the landings by the nominal CPUE. For each year the CPUE was calculated over a period including the previous fourth quarter and the first quarter of the year in question. Interviewed landings were divided by interviewed effort. These were selected using a 40% qualification level as described in Westrheim and Foucher 1987. This was done to avoid splitting the main period of the fishery (October-March) between two years. Also, fish present during the fishery in these quarters give an indication of the parent stock that will produce the new year-class.

By minor Statistical Area, landings decreased in all areas except Area 19 in 1988 compared to 1987. Landings in Area 20 (Victoria) increased by a further 80%. In January-June 1989 landings decreased, relative to January-June 1988, in all areas.

3.2.3. Yield Options

Regulation does not appear to be necessary at this time. There are no symptoms of overfishing and current minimum mesh-size is reasonably satisfactory with respect to optimizing catch profitability (Westrheim and Foucher 1987).

3.3. West Coast of Vancouver Island (Areas 3C and 3D)

3.3.1. Introduction

Pacific cod is the principal shelf species sought by the on-bottom trawl fishery off the west coast of Vancouver Island. Area 3C produces approximately 90%, and Area 3D, 10% of the total nominal catch (landings) for the two areas combined. Within Area 3C, principal trawling grounds are Amphitrite Bank (53% of Area 3C landings), Big Bank (28%), and Swiftsure Bank (14%) (Foucher and Westrheim 1984). Amphitrite Bank is a major spawning ground for cod, and 77% of its production historically (prior to 1980) occurs during January-March. Big Bank and Swiftsure Bank are feeding areas with most catch occurring primarily during April-September -- 79% and 89%, respectively. The trawl fishery on spawning cod began about 1961, assumed considerable importance after 1971, and has been subject to various conservation regulations since 1977, most recently (1988) closures during the months of January, February and March on the spawning grounds. Only the first 14 days of each month were open during this period.

3.3.2. Landing Statistics

Landing statistics are based on Foucher (1987) for detailed records by ground. Effort was allotted to the mixed-species fishery using the method of Westrheim (1983), and standardized according to the method of Westrheim and Foucher (1985a). Essentially, the standardization was a linear function utilizing vessel horsepower as the single factor in the regression. Representative nominal CPUEs for the region were derived from Canadian records for Big Bank, April-September. Landings, effort and CPUE have all fluctuated substantially (Table 3.2; Fig. 3.2). Landings for Areas 3C and 3D to June 30, 1989 were 2353 t compared to 1448 t for the same period in 1988.

3.3.3. Age Composition

Age compositions are derived from length frequencies for Canadian cod landings using the method of Foucher and Fournier (1982). Age-classes 2-4 predominate in the landings, and few cod landed from the west coast of Vancouver Island are older than age 7 (Table 3.2). Recruitment is considered complete at age 3 under present fishery conditions. Year-class abundance during 1962-86, based on CPUE at age 2, fluctuates substantially --0.8 cod/h in 1985 to 125.6 cod/h in 1971. Data prior to 1962 are questionable due to the dissimilarity of the Canadian and U.S. trawl fleets at that time, and the absence of detailed records of the catches by U.S. vessels. Possible problems with accurately determining the proportions of older groups were pointed out by Westrheim and Foucher 1985b.

We plotted the length-frequency distributions of 3C cod for the second quarter of the year for the past three years (1987-89) in order to look at the relative abundance of the recruiting age-2 and age-3 fish (Fig. 3.3). The long-term mode of the age-2 fish was taken at approximately 44 cm, and the modal length of the age-3 fish at 55 cm (Ketchen 1964). It was clear that in 1988 and 1989 there were few age-2 fish as compared to 1987, when there was an abundance of 2-year olds from the 1985 year-class. By 1988 the 1985 year-class was showing as an abundance of 3-year olds. We conclude that recruitment from the 1986 and 1987 year-classes was much less than that from 1985.

3.3.4 Mortality Rates

The derivation of mortality rates previously described (Foucher and Tyler 1988) resulted in best estimates for this area of:

Instantaneous fishing mortality rate	0.50
Instantaneous natural mortality rate	0.69
Instantaneous total mortality rate	1.19

The natural mortality rate was rounded to 0.7 for the following analyses. The age determination process is still under study. A comparison of age compositions derived by the length-frequency method, which was used to produce the time-series of ages used, and the fin-ray method is in progress.

3.3.5 Virtual Population Analysis

A virtual population analysis (Gulland 1983) was undertaken utilizing the mortality rates estimated for ages 4-5: terminal F at age 7 = 0.5; M = 0.7 for all ages. Terminal F was allowed to vary around 0.50 by first calculating an overall q:

$$q = F / E, \quad \text{where } E = \text{mean effort}$$

and then calculating terminal F for each year:

$$F = q * E, \text{ where } E \text{ is the effort for that year.}$$

This allowed the terminal F value to vary with effort which is more realistic than holding it constant for all years. Estimated numbers present (for age-classes represented by ages 2-7 -- 1954-79) at age 2 ranged from 0.8 million in 1982 to 9.1 million in 1971 (Table 3.3). Mean values of F by age-class were 0.08, 0.33, 0.54, 0.64, 0.66, and 0.50 for ages 2-7, respectively (Table 3.4). Mean exploitation rates for the time series were 0.05, 0.20, 0.29, 0.33, 0.33, and 0.28 for ages 2-7, respectively (Table 3.5).

3.3.6. Condition of the Stock

The beginning of a fishery concentrating on spawning cod on Amphitrite Bank coincided with the start of a relatively steady decline in abundance after the early 1970s. In response to this heavy fishing pressure, a predictor was developed to forecast the probable January-March landings from Area 3C. This was based on the landings from the previous second and third quarters (Ketchen 1980).

Later, Big Bank, April-September was chosen as the representative area-time cell from which to calculate CPUE for Area 3C as a whole (Foucher and Westrheim 1984), and this has subsequently been used as an abundance index for the Area 3C stock. The index increased from 126 kg/h in 1987 to 204 kg/h in 1988 due largely to the 1985 year-class. Preliminary data for 1989 indicate the peak may have been reached in 1988 -- CPUE for April-June 1989 is 194 kg/h. The final CPUE value for the stock will include the period April-September inclusive.

On the basis of the current good condition of the stock and the state of the fishery and its markets, it would seem reasonable to open the area for a winter fishery. A history of the closures and associated landings follows:

			Area 3C landings		Big Bank CPUE for	
Year	Closed period(s)	Total no. days open	Jan-Mar[a] (t)	Jan-Dec (t)	Previous Q2-3	Following Q2
1978	Feb 22 - Apr 3	53	895	1878	146	194
1979	Feb 1 - Mar 31	31	303	1677	167	212
1980	Jan 1 - Mar 31	0	1	977	220	131
1981	Jan 1 - Mar 31	0	5	856	124	39
1982	Jan 1 - Jan 31	59[b]	624	1086	60	24
1983	Jan 1-20, Feb 6-17	58	113	674	35	85
1984	No closure	91	290	643	66	42
1985	Jan 1 - Mar 31	0	124	449	33	11
1986	Jan 1 - Mar 31	0	44	424	13	26
1987	Jan 1 - Mar 31	0	18	747	37	200
1988	Jan 15-31, Feb 15-29, Mar 15-31	42	561	1652	126	268
1989	No closure	90	1880	-	-	-

[a] The closure, in some years, did not include all of Area 3C.

[b] In February and March 1982 a trip limit of 50,000 lb per trip with two trips allowed per boat per month was imposed.

The CPUE for the April-September index period reached its lowest point in 1985, one year after the last of three consecutive winter openings (1982-84) and then began to recover in response to a strong year-class possibly contributed to by the more strict conservation measures starting in 1985. The higher CPUE in quarters 2-3 of 1987 (126) suggested that CPUE would be good for the first quarter of 1988. However, because this was from only one age-class and the stock was so low, only a partial opening was implemented. The resulting landings were 561 t. The CPUE of the following quarter 2, which was the highest since 1972, indicated that the recovery was being sustained and suggested that the stock was no longer in need of protection. The indicator will continue to be monitored and, due to the short life-span of a cod year-class in the fishery, regulations to limit catch may have to be imposed again in the future.

3.3.7. Yield-per-recruit analysis

The optimal yield-per-recruit was investigated using a minimum commercially acceptable size of 41 cm, a mesh size of 5.3 in. and natural mortality rates of 0.6, 0.7, and 0.8. At a value of M = 0.6, that is probably representative, yield-per-recruit rises more rapidly to a higher level, peaks at F= 0.6 and then drops gradually as F increases (Fig. 3.4). More details and a figure are given in Tyler and Foucher 1989.

3.3.8. Yield Options

With the stock appearing to be strong it does not appear necessary to impose a spawning season closure for the first quarter of 1990 as has been done in recent years.

3.4. Queen Charlotte Sound (Areas 5A and 5B)

3.4.1. Landing Statistics

Nominal catch (landings) in 1988 was 1859 t from 5A and 5B combined (Table 3.6), a decrease of 43% from 1987 landings. They were still more than 40% greater than the average annual landing level from Queen Charlotte Sound. Landings in 1989 are continuing to decrease from these high levels. In 1989, January-June landings were 292 t compared to 860 t in 1988.

3.4.2. Condition of the Stock

No port samples were collected during 1988.

The 1984 assessment (Westrheim and Foucher 1985b) indicated that there was little danger of overfishing because of extensive, rough-bottom refuges from trawling. However, the dramatic drop in landings from 1987 levels indicates that the very high catch levels may have harvested much of the 1985 year-class during their first three years in the fishery.

3.4.3. Yield options

No recommendation is made for the fishery in Queen Charlotte Sound. Overfishing by a trawl fishery in 5A/5B is considered unlikely due to the extent of untrawlable bottom at depths frequented by Pacific cod.

3.5. Hecate Strait (Areas 5C and 5D)

3.5.1. Introduction

The stock of Pacific cod in Hecate Strait is the largest in the Canadian Fishery Zone. During 1987 when the coastwide cod catch was higher than in any of the previous decades (and since), 8870 t came from Hecate Strait out of 13940 t for the entire coast (rounded figures), i.e., 64%. As with other Canadian Pacific cod stocks, recruitment and subsequently total biomass, fluctuates widely from natural causes, exhibiting 199% shifts in biomass since 1970 (8825 t in 1982 and 17576 t in 1974, based in VPA).

3.5.2. The Fishery

Nominal catch from Hecate Strait is divided between two major areas and several important grounds (Fig. 3.5). Nominal catch from the northern area (5D) was 6337 t in 1987, and 3873 t in 1988. Catch from the southern area of the Strait (5C) was 2533 t in 1987 and 2323 t in 1988. In 1989 following the spawning period, fishing captains reported to port samplers that cod were in scattered groups in the Strait. At the same time market conditions were poor.

3.5.3. Landing Statistics

Effort (Table 3.7; Fig. 3.6) was fairly constant up to the mid-1960s, after which there was a series of irregular oscillations, likely in response to strong year-classes. Effort tended to increase following strong recruitment, then decrease with a lag one or two years after catch and nominal CPUE fell off. Since 1982, effort has remained fairly constant at below 8000 h (until 1988). Nominal CPUE also oscillated but not synchronously with landings. A long, low period in landings and CPUE ended with the entry of the strong 1985 year-class. The higher level of production continued into 1988. Landings to June 30, 1989 were 4204 t compared to 5055 t for the same period in 1988. Mean for landings for Jan 1-Jun 30 over 1956-87 is 2394 t.

3.5.4. Age Composition

Annual age composition in numbers landed per hour trawled (Table 3.7) shows that ages 2-4 are most important to the fishery. Recruitment of age-2 fish begins historically in the spring, but more recently in the winter. In recent years, recruitment is complete by age 3 (unpublished observer data), but in the past by age 4. Strong year-classes, based on CPUE at age 2 (>100/h), are 1960-62, 1965, 1970-72, 1977 and 1985, which, by this measure, is the strongest year-class observed in this time-series. There is evidence that the 1986 year-class is above average.

We plotted the length-frequency distributions of the combined cod samples of 5C and 5D, for the first quarter of the year, for each of 1987-89 to look at the relative abundance of the recruiting age-2 and age-3 fish (Fig. 3.7). We used the first quarter in this case because in Hecate Strait there was a substantial fishery during this quarter. This was prevented by regulations for the SW Vancouver Island area, and so, in that area, we examined the second quarter data -- section 3.3.3. Again the long-term mode was taken at 44 cm for age-2's, and 55 cm for age-3's (Ketchen 1964). In 1986 there were relatively few age-2 and age-3 fish due to the poor recruitment in 1984 and 1983. The 1987 length frequency was quite different from the 1986 data, and showed an enormous influx of age-2 fish from the

1985 year-class. By the first quarter of 1988, this year-class still dominated the catch, despite the record catches that were taken during 1987. Yet it was clear that there was a substantial, new recruitment of age-2 fish from the 1986 year-class, indicated by the relatively large number of fish at approximately 44 cm.

3.5.5. Mortality Rates

The method of calculation of mortality rates was reported in Foucher and Tyler 1988. The best estimate of the parameters was considered to be those for ages 4-5: M = 0.61 and F = 0.52. These were rounded to M = 0.6 and F = 0.5 for the following analysis.

3.5.6. Virtual Population Analysis

Virtual population analysis was carried out as described in section 3.3.5. The VPA estimates of cod at age-2 ranged from 2.8 million in 1968 to 17.5 million in 1987 (Table 3.8). Mean values of F by age-class were 0.14, 0.38, 0.58, 0.62, 0.63 and 0.50 for ages 2-7, respectively (Table 3.9). Mean exploitation rates were 0.09, 0.23, 0.33, 0.34, 0.34, and 0.29 for ages 2-7, respectively (Table 3.10).

3.5.7 Calibration of Nominal CPUE Values using VPA

One of the most useful aspects of VPA is that the results are expressed in terms of absolute numbers-at-age. Because the procedure involves back-calculations on the catches and depends on accumulated F, however, these estimates are not available for the current year, and are unstable for the most recent three years. The length of the series depends on the intensity of the fishery, and how many years it takes accumulated F on a cohort to reach a total of 2.0 or more (Pope 1972). Stock assessment biologists have sometimes moved around this obstacle to absolute estimates by regressing numbers at age (from VPA) on CPUE from either the commercial fishery or from research surveys. They then use the relationship to re-scale the most recent CPUE-at-age figures to number at age. To be sure, these estimates are not as good as true VPA estimates, and are worse than the original CPUE figures in that they incorporate extra measurement error and process error. Still the procedure gives the modeller some time-advance for yield estimation.

We have carried out a series of regressions to find which ages supply the tightest relationship between VPA numbers and CPUE (kg/h) for Hecate Strait Pacific cod.

Equation	Year range	No. years	r^2
VPA2 = 3918 + 21.4 CPUE2	1961 - 82	22	60.5*
VPA3 = 1334 + 12.7 CPUE3	1961 - 83	23	86.0*
VPA4 = 479 + 9.6 CPUE4	1961 - 84	24	78.5*
VPA5 = 233 + 6.6 CPUE5	1961 - 85	25	23.9

* indicates significance at the 0.05 level
VPA2 and CPUE2 are age-2 specific values

Because of the high r^2 value, we chose the age-3 regression to scale CPUE at age-3 to numbers at age-3. The scatter plot with regression line (Fig. 3.8) gives some reason for optimism. The converted age-3 CPUE values, in millions of fish, for 1984 to 1987 calendar years (1981-1984 year-classes) are, respectively: 1.944, 1.726, 1.919, 2.427. Whether this re-scaling of CPUE values is at all accurate will be tested as true VPA values for these year-classes become available.

We also regressed the tonnes of biomass from VPA of the recruited stock (calculated from Table 3.8) against the index of abundance for the recruited stock (CPUE, kg/h, Table 3.7) to get a scaling relationship for conversion of stock CPUE to tonnes.

$$\text{VPA} = 8675.8 + 14.452\ \text{CPUE}$$

The 23-year period used was 1961 to 1983, inclusive. The correlation between the two time-series is statistically significant ($r = 0.86$, $p > 0.05$, Fig. 3.9). We used this equation for scaling in the simulation analysis (Section 3.5.10).

3.5.8. Condition of the Stock

The abundance index for Pacific cod in Hecate Strait, calculated from the CPUE from Horseshoe and Two Peaks-Butterworth during April-September (Table 3.7) indicated a decrease in abundance. The index decreased from 1127 kg/h in 1987 to 727 kg/h in 1988. Data for 1989 indicated a further decline to 380 kg/h (based on April-June only). Still, the stock size was above the mean of 214 kg/h for the period 1962-81. We took the mean of this 20-year period to be a bench mark figure because effort data were improved in quality since 1962, and because the series just included three upward and three downward stock swings.

3.5.9. Yield-per-recruit Analysis

The optimal yield-per-recruit was investigated using natural mortality rates of both 0.4 and 0.6 and other parameters as described in Section 3.3.7. The resulting yield-per-recruit vs F curve for $M = 0.6$ (Fig. 3.10) rises rapidly from the origin and then shows very little variation in yield-per-recruit above $F = 0.5$. At a lower value of M (0.4) yield-per-recruit rises even more rapidly from the origin to a higher peak at $F = 0.4$ and then drops off steadily. The mean historic F was estimated at 0.52, giving support to the hypothesis that the fishery has been self-regulating in terms of yield-per-recruit.

3.5.10 Simulation Analysis

The calculations in the model follow the age-structured, Self-Generating Model described in Tyler and Gallucci (1980), and is an adaptation of fairly standard calculation procedures. Catch in numbers at age is calculated using the Baranov Catch Equation:

$$C_i = N_i \ (F/F+M) \ (1-e^{-F-M})$$

where i is age, C_i is catch at age in number, N_i is number of fish at age, F is instanteous fishing mortality, M is instanteous natural mortality, and e is the base for natural logarithms. We used a previously estimated value of $M = 0.60$ (Tyler and Foucher 1989). Number at age is updated each year using the negative exponential survival function:

$$N_{i+1} = N_i \ (e^{-F-M})$$

Biomass at age was calculated in the model with a look-up table giving weight at age. The length data for age-1 fish were from Ketchen (1964), while the data for other ages were from a modal analysis of recent length frequencies (text table below). The length-frequencies represented the period 1960-1987, inclusive, for the second quarter of the year. Lengths were converted to weight using a relationship from Westrheim (1977) for Hecate Strait females in July. These weights were used because they represented the middle of the fishery year.

Age	Length (cm)	Weight (g)
1	32.9	352
2	49.1	1274
3	58.1	2188
4	65.6	3231
5	71.6	4279
6	76.5	5292
7	81.2	6409
8	84.3	7228
9	86.2	7765
10	91.0	9240

Recruitment was added using a model developed by Tyler and Crawford (MS unpublished) that was similar in procedure and findings to that of Tyler and Westrheim 1986. In the latter a multivariate, second-order fitting of age-3 recruits was made using a new index of northward transport of water in February (the spawning period), and adult stock size. The fit of the Tyler-Crawford recruitment model was made with the Schnute-McKinnell Response Surface Analysis (Schnute and McKinnell 1984). The data used was catch per unit effort (CPUE) for age-3 fish, and also CPUE for the combined structure of the recruited stock. This data was in units of numbers per hour for the age-3's, and kg per hour for the adult stock. A recruitment curve for age-3's was calculated for mean transport values. After the fitting was completed the variables were rescaled to absolute numbers and biomass using linear regressions between CPUE and values from virtual population analysis (VPA) from data derived from commercial catch statistics (see Section 3.5.7). Points for this curve were then used as data and re-fitted with a Ricker function:

$$R = S[e^{a(1-(b\ S))}]$$

where R is recruits in number of age-3 fish, S is the parent stock size in tonnes, and a, b are parameters fitted using the least squares and the log-linearized version of the Ricker function (a=6.0127, b=1.0205 X 10-5).

The simulation model incorporating the Ricker function was used to determine the spawning biomass at equilibrium with no fishery by setting F=0, and iterating to 1000 years. The initial age-class structure of the stock was from VPA values for number-at-age. This resultant equilibrium biomass was 8300 t. With a similar procedure and a series of F values ranging from 0.01 to 2.0, the model was used to calculate the spawning biomass that gave maximum surplus annual production (i.e., potential maximum yield). This biomass value was 4000 t. We have called this value the "critical spawning biomass", because thinning the stock down from the equilibrium level of 8300 t to 4000 t produced higher yields, while further reduction in spawning stock biomass caused progressive yield reductions. Since this value maximized yield it may also be termed B_{opt}. The response surface analysis has shown that the shape of the stock-recruitment curve was independent of the northward transport, but that the magnitude of recruitment was strongly dependent on transport (Tyler and Crawford, unpublished MS). This means that the critical spawning biomass was relatively constant through different levels of transport, and that the value could be used in developing stock assessments despite transport fluctuations. The stock may be fished hard enough in any year to reduce its size down to the critical spawning biomass. Reduction lower than that value would cause recruitment overfishing.

To estimate the maximum yield for the stock in 1990 that would not cause recruitment overfishing, we initialized the simulation model with the 1988 age structure from VPA (see Section 3.5.6), and estimated the number of recruits in 1988, 1989 with the recruitment response surface (Tyler and Crawford, unpublished MS.). We inserted these recruitment estimates into the model, substituting these specific recruitment values in place of the stock-recruitment relationship referred to above. To simulate potential yield we needed an F value for 1988, 1989, and 1990, and used an iterative procedure to solve for F, adjusting F in successive simulation runs for all fully recruited ages (3-10) until the model calculated the approximate level of the 1988 catch. We then set the F for the partially recruited age-2 fish at slightly more than half of the adjusted F. The 1988 catch was well simulated when we used the resulting F = 0.40 along with F = 0.25 at age-2. Since the actual yield in 1988 was 6196 t, while the simulated yield was 6980 t (text table below), the model seemed to be tracking the stock within 13%.

The forward simulation was done for three years, 1988, 1989, and 1990. The year of particular interest for stock assessment purposes and estimation of potential yield was 1990.

Stock and yield values estimated from simulation. Units are tonnes.

Year	Biomass	Spawning biomass	Potential yield	Simulated yield
1988	12699	8436	18758	6980
1989	9478	6303	5983	5102
1990	7475	4364	3851	3744

The values for the stock biomass and the spawning biomass (text table above) were given at year-end after fishing and natural mortality. The stock biomass is much greater than the spawning biomass (text table above) because of the presence of immature age-1 and age-2 fish. These values were backcalculated from age-3 numbers using the value of M for age-3 fish. As age-1 and age-2 fish probably experience a higher mortality, the biomass at age-1 would be a gross under-estimate, and the actual stock biomass would be much larger that the simulated one.

The fishing mortality rate used in 1989 and 1990 was the same as used for 1988. Poor market conditions of 1989, combined with the published observation (Tyler and Foucher 1989) that F has often been low when cod biomass was low (text table above) led us to make the assumption that F in 1989 and 1990 would not be greater than it was in 1988 (actual 1989 yield was not available at the time of writing). The potential yield was determined for the start of the year, and included the catch of age-2 fish, summed with the balance between the spawning biomass at the begining of the year and the critical spawning biomass of 4000 t. The simulated yield was what would be taken if the fishing mortality rate from 1988 were applied to 1989 and 1990. The results were that 3800 t would be available to the fishery in 1990 (truncated from 3851 in text table). In fact if the rate of fishing for 1988 were roughly repeated in 1990, the fishery would actually not quite take the potential yield, but would catch 3744 t (text table above).

To check the stock history for the possibility of recruitment overfishing, we supplied the model with the historic recruitment and annual mean F from published VPA (Section 3.5.6). We examined the period 1972 to 1985. While the stock made a strong recovery in 1972, and another recovery in 1986, this period is a critical one for possible overfishing because of the continuous period of low stock sizes from 1980 to 1986. We plotted the historic yield and also the spawning biomass calculated by the model with yield removed (Figure 3.11). After 1980, the spawning biomass tended to be close to the critical spawning biomass, sinking slightly below on two occasions, 1981 and 1984. It was clear that recently the fleet has had the capacity to fish down the Hecate Strait stock, and that marginal overfishing occurred in these two years.

3.5.11 Yield Options

The 1988 recommendation was that there be no quota or other restrictions to the fishery (Tyler and Foucher 1989). The CPUE in 1986 was the highest for the previous ten years and in 1987 had increased again by 177% over 1986 levels due to the strong 1985 year-class. This year-class contributed strongly to the 1988 fishery, and the effect was still felt in 1989. However, mortality rates were high enough that by 1990 there would be little significant contribution from the 1985 year-class.

Recruitment in 1988 and 1989 is expected to be moderate but not strong, based on the oceanographic response surface (Tyler and Crawford, unpublished MS). Dependency on a correlation, even one that has been demonstrated to make good predictions beyond the dates of the time series as is the case here, has substantial risk. However the estimate of potential yield for 1990 is only partially dependent on this correlation. The biomass of the partially recruited age-2 fish in 1990 is entirely from the prediction of the response surface, but only 19% of the total estimate of potential yield (745 t of the 3851 t) is from this source and unverified. The age-3 biomass is from the response surface, but has been verified by comparison with the length-frequency samples taken by port sampling during the first quarter of 1989. All of the biomasses of the age-4 and older fish have been verified with length frequencies from the fishery, and are derived from VPA instead of the response surface. Finally the quota is provisional on the verification of the age-2 abundance estimate with the length frequencies taken in the first quarter of the new year (1990). If the estimate is not verified, and a very strong year-class of two-year-olds is indicated, the quota will be adjusted upward by 2000 t, which is approximately 60% of the age-2 catch made in 1987 when the exceptionally large 1985 year-class recruited to the fishery. If on the other hand an extremely weak abundance of age two's is indicated, the provisional quota would be put into place for the year and an adjustment made in the following year. Thus the provisional quota is the minimum available to the fishery for the year. We recommend that catch of Pacific cod in Hecate Strait be limited provisionally to 3800 t in 1990. Based on the range of fluctuation in simulated spawning biomass between 1980 and 1987, which we interpret as random fluctuation, we expected the model to be accurate within 2000 t, after the first quarter verification. Therefore the range of biologically acceptable levels would be 2800 t to 4800 t, with the possible addition of an extra 2000 t.

To summarize:

Low-risk sustainable level: 2800 t

Sustainable level: 3800 t

High-risk sustainable level: 4800 t

The selected quota should be carried as provisional until April 1, 1990 because of the entry into the fishery of age-2 fish during the first quarter of the year. By that date the length-frequency distributions sampled from the first three months of the 1990 fishery will provide a verification of the relative abundance to age-2 cod, and a firm quota can be put in place. Three possibilities exist:

a. If the presently estimated abundance of age-2's is verified, the provisional quota can be made firm.

b. If the verified abundance of age-2 fish is substantially lower than the presently estimated abundance the provisional quota can be made firm. An adjustment will be made in next year's stock assessment.

c. If the verified abundance is substantially higher than the presently estimated abundance, the quota selected above should be increased by 2000 t. A further adjustment will be made in next year's assessment when the strength of the year-class becomes more clear.

Table 3.1. Canadian annual nominal catch (landings), standardized equivalent effort and nominal CPUE for Pacific cod from the Strait of Georgia and vicinity (Area 4B), 1954-88.

Year	Landings (t)	Effort (h)	Nominal CPUE (kg/h)
1955	967	5825	166
1956	578	3635	159
1957	607	2961	205
1958	650	3421	190
1959	1047	4552	230
1960	744	4203	177
1961	415	2660	156
1962	479	3656	131
1963	677	3959	171
1964	713	5893	121
1965	484	2798	173
1966	297	2357	126
1967	475	1439	330
1968	349	2815	124
1969	388	3495	111
1970	502	3138	160
1971	740	3008	246
1972	630	2203	286
1973	441	2273	194
1974	681	2308	295
1975	991	4464	222
1976	927	3911	237
1977	1148	4042	284
1978	1373	5029	273
1979	1197	3706	323
1980	1606	7470	215
1981	1742	6598	264
1982	1011	3717	272
1983	907	4104	221
1984	652	3047	214
1985	463	1508	307
1986	803	2848	282
1987	1015	2843	357
1988	1220	3020	404

Table 3.2. Canada-U.S.[a] annual nominal catch (landings), standardized equivalent effort (h), overall nominal CPUE and number/h, by age, for Pacific cod from the west coast of Vancouver Island (Areas 3C+3D), 1956-88.

				Age								
Year	C-US Land (t)	C-US Eff (h)	C-US CPUE (kg/h)	1	2	3	4	5	6	7	8	9
1956	1468	9009	163	-	8.6	21.1	19.9	9.0	0.8	0.6	0.3	-
1957	1814	13538	134	-	16.3	19.2	10.2	5.9	1.4	0.3	0.1	0.1
1958	850	7659	111	-	1.8	34.7	6.3	2.7	0.5	0.2	-	-
1959	907	20155	45	-	1.3	6.4	5.5	1.3	0.1	0.1	-	-
1960	635	10079	63	-	0.4	13.7	7.2	2.2	0.4	-	-	-
1961	420	19998	21	-	0.5	1.6	3.8	1.7	0.1	0.1	-	-
1962	633	16230	39	-	13.9	3.5	2.2	0.9	0.2	-	-	-
1963	1231	9770	126	-	33.9	17.5	7.2	1.5	0.2	0.2	-	-
1964	1221	3569	342	-	23.1	47.8	38.9	19.0	7.2	0.9	0.5	-
1965	2768	12361	224	-	15.4	47.5	20.6	5.5	1.7	0.4	0.1	-
1966	3136	13108	239	-	16.2	49.7	23.7	6.3	2.3	0.4	-	-
1967	1941	24887	78	-	2.2	16.8	7.9	1.3	1.0	0.1	0.1	-
1968	1425	17378	82	-	3.7	15.0	6.7	2.8	1.0	0.4	0.1	-
1969	1092	15825	69	-	5.0	12.2	5.3	2.3	1.1	0.4	0.2	-
1970	1095	7879	139	-	28.9	19.2	13.0	3.5	0.7	0.2	0.1	-
1971	3328	6631	502	1.4	125.6	86.0	18.0	5.7	1.7	0.9	0.4	-
1972	5629	10846	519	0.9	113.3	86.8	27.6	7.6	1.4	0.7	0.4	-
1973	3712	17345	214	-	9.7	35.9	19.6	6.4	2.3	0.4	0.1	-
1974	3474	18094	192	-	27.2	13.0	23.2	8.9	2.4	0.9	0.4	0.1
1975	4000	24847	161	-	13.8	36.2	9.2	4.3	2.1	0.3	0.2	-
1976	3797	21215	179	-	8.5	35.6	21.3	5.6	0.7	0.3	0.2	-
1977	2948	20192	146	-	11.5	21.0	16.0	5.3	1.8	0.5	0.2	-
1978	1998	11965	167	0.1	7.3	34.6	15.4	6.3	0.9	1.2	0.1	0.1
1979	1861	8461	220	0.1	26.2	32.7	19.5	8.7	1.5	0.6	0.2	0.1
1980	1152	9291	124	0.6	22.3	14.3	10.6	5.1	2.0	0.1	-	0.1
1981	918	15298	60	0.3	4.8	19.4	2.7	0.6	0.6	0.3	-	-
1982	1123	32086	35	-	2.7	6.6	3.7	1.2	0.4	0.2	-	-
1983	694	10516	66	-	16.3	7.2	8.6	1.9	1.3	0.1	-	-
1984	675	20455	33	-	4.1	6.8	3.2	1.3	0.2	0.1	-	-
1985	493	37923	13	-	0.8	4.6	0.8	0.1	-	-	-	-
1986	498	13458	37	-	2.1	4.7	6.3	1.2	0.2	-	-	-
1987	810	6428	126	-	63.8	6.3	7.4	6.0	0.6	-	-	-
1988	1803	8838	204	-	13.6	57.5	18.5	2.2	1.4	0.9	-	0.3

[a] No U.S. landings after March 31, 1981.

Table 3.3. Virtual population analysis estimates of numbers-at-age (thousands) of Pacific cod from the west coast of Vancouver Island (Areas 3C and 3D), for age-classes 2-7, 1956-88. (Asterisks indicate estimates considered inaccurate -- cumulative F for year-class less than 2.0 -- Pope 1972.)

	Age					
Year	2	3	4	5	6	7
1956	1576	767	513	202	36	27
1957	1990	728	252	135	47	13
1958	1539	838	190	36	16	10
1959	2397	754	238	62	5	5
1960	1725	1174	286	45	14	1
1961	2535	851	487	93	8	4
1962	3189	1251	399	190	24	2
1963	4411	1433	582	173	85	9
1964	4857	1960	593	240	76	41
1965	4403	2360	857	201	74	21
1966	3963	2049	776	254	55	22
1967	2971	1828	581	181	71	8
1968	2584	1442	629	159	68	19
1969	4573	1238	537	232	46	22
1970	6320	2217	483	209	90	11
1971	9141	2984	996	169	85	41
1972	8125	3947	1091	412	58	35
1973	6189	3191	1320	342	150	19
1974	8009	2965	1162	428	96	48
1975	5519	3648	1312	298	106	19
1976	4211	2514	1200	496	76	18
1977	3496	1974	742	294	166	27
1978	1890	1571	691	156	75	58
1979	1794	880	503	218	28	30
1980	1990	738	251	140	60	6
1981	1486	850	275	59	38	17
1982	804	687	224	108	23	12
1983	2338*	340	199	34	27	4
1984	2013	1045*	118	39	4	5
1985	891*	944	422*	16	3	0
1986	2213*	421*	351	187*	4	1
1987	5590*	1076*	166*	117	82*	1
1988	2481*	2499*	508*	50*	32	38*

Table 3.4. Virtual population analysis estimates of fishing mortality rate (F) for Pacific cod from the west coast of Vancouver Island (Areas 3C and 3D), for age-classes 2-7, 1956-88.

	Age					
Year	2	3	4	5	6	7
1956	0.07	0.41	0.64	0.75	0.34	0.30
1957	0.16	0.64	1.24	1.45	0.81	0.45
1958	0.01	0.56	0.42	1.36	0.45	0.26
1959	0.01	0.27	0.97	0.78	1.33	0.67
1960	0.01	0.18	0.42	1.02	0.54	0.34
1961	0.01	0.06	0.24	0.66	0.59	0.67
1962	0.10	0.06	0.13	0.11	0.24	0.54
1963	0.11	0.18	0.19	0.12	0.04	0.33
1964	0.02	0.13	0.38	0.48	0.60	0.12
1965	0.06	0.41	0.51	0.60	0.50	0.41
1966	0.07	0.56	0.75	0.58	1.22	0.44
1967	0.02	0.37	0.60	0.28	0.62	0.83
1968	0.04	0.29	0.30	0.55	0.43	0.58
1969	0.02	0.24	0.24	0.25	0.72	0.53
1970	0.05	0.10	0.35	0.20	0.09	0.26
1971	0.14	0.31	0.18	0.37	0.20	0.22
1972	0.23	0.40	0.46	0.31	0.43	0.36
1973	0.04	0.31	0.43	0.57	0.44	0.58
1974	0.09	0.12	0.66	0.70	0.90	0.60
1975	0.09	0.41	0.27	0.67	1.08	0.83
1976	0.06	0.52	0.71	0.40	0.33	0.71
1977	0.10	0.35	0.86	0.67	0.35	0.67
1978	0.06	0.44	0.45	1.03	0.22	0.40
1979	0.19	0.55	0.58	0.60	0.90	0.28
1980	0.15	0.29	0.75	0.60	0.55	0.31
1981	0.07	0.63	0.23	0.22	0.43	0.51
1982	0.16	0.54	1.19	0.68	1.14	1.07
1983	0.11	0.36	0.93	1.38	1.08	0.35
1984	0.06	0.21	1.29	1.93	2.44	0.68
1985	0.05	0.29	0.11	0.60	0.64	1.26
1986	0.02	0.23	0.40	0.12	1.43	0.45
1987	0.11	0.05	0.49	0.59	0.07	0.21
1988	0.08	0.33	0.54	0.64	0.66	0.29
Mean	0.08	0.33	0.54	0.64	0.66	0.29

Table 3.5. Virtual population analysis estimates of annual exploitation rates for Pacific cod from the west coast of Vancouver Island (Areas 3C and 3D), age-classes 2-7, 1956-88.

	Age					
Year	2	3	4	5	6	7
1956	0.05	0.25	0.35	0.40	0.21	0.19
1957	0.11	0.36	0.55	0.60	0.42	0.27
1958	0.01	0.32	0.26	0.58	0.27	0.16
1959	0.01	0.17	0.47	0.41	0.57	0.37
1960	0.00	0.12	0.26	0.48	0.31	0.21
1961	0.00	0.04	0.16	0.36	0.33	0.36
1962	0.07	0.05	0.09	0.07	0.15	0.31
1963	0.08	0.12	0.12	0.09	0.02	0.20
1964	0.02	0.09	0.23	0.28	0.34	0.08
1965	0.04	0.25	0.30	0.34	0.29	0.25
1966	0.05	0.32	0.40	0.32	0.54	0.26
1967	0.02	0.23	0.34	0.18	0.34	0.42
1968	0.03	0.18	0.19	0.31	0.26	0.33
1969	0.02	0.16	0.16	0.16	0.38	0.30
1970	0.04	0.07	0.21	0.13	0.06	0.17
1971	0.09	0.19	0.12	0.22	0.13	0.14
1972	0.15	0.24	0.27	0.20	0.26	0.22
1973	0.03	0.20	0.26	0.32	0.26	0.33
1974	0.06	0.08	0.36	0.37	0.45	0.34
1975	0.06	0.25	0.17	0.36	0.50	0.42
1976	0.04	0.30	0.38	0.24	0.20	0.38
1977	0.07	0.21	0.44	0.36	0.22	0.37
1978	0.05	0.26	0.27	0.49	0.14	0.24
1979	0.12	0.31	0.33	0.34	0.45	0.18
1980	0.10	0.18	0.39	0.34	0.31	0.19
1981	0.05	0.35	0.15	0.15	0.26	0.30
1982	0.11	0.31	0.53	0.37	0.52	0.50
1983	0.07	0.22	0.46	0.58	0.51	0.22
1984	0.04	0.13	0.56	0.68	0.75	0.37
1985	0.04	0.18	0.07	0.34	0.36	0.55
1986	0.01	0.15	0.24	0.09	0.59	0.27
1987	0.07	0.04	0.29	0.33	0.05	0.14
1988	0.05	0.20	0.31	0.35	0.36	0.19
Mean	0.05	0.20	0.29	0.33	0.33	0.28

Table 3.6. Canada-U.S. annual nominal catch (landings), standardized equivalent effort, nominal CPUE and CPUE by age (number per hour), for Pacific cod from Queen Charlotte Sound (Areas 5A + 5B), 1956-88.

	C-US Land	C-US Eff	C-US CPUE	Age										
Year	(t)	(h)	(kg/h)	1	2	3	4	5	6	7	8	9	10	11
1956	1753	5312	330	0.1	71.4	52.9	13.8	0.4	4.5	-	0.1	0.5	-	-
1957	2744	3532	777	6.3	197.5	105.6	32.3	5.4	1.3	0.3	0.2	0.3	-	-
1958	1178	5583	211	-	14.1	35.7	18.6	5.5	0.8	0.7	0.1	0.1	-	-
1959	946	4078	232	0.1	32.6	32.3	15.3	5.3	2.1	0.4	0.2	-	-	-
1960	618	4791	129	-	3.1	15.6	11.6	5.0	2.2	0.6	0.2	0.1	-	-
1961	240	3692	65	-	2.2	5.3	4.7	4.1	2.0	0.2	0.3	-	-	-
1962	422	4538	93	-	14.6	6.2	6.1	3.7	4.3	2.4	0.8	0.1	0.1	-
1963	677	4153	163	0.3	29.1	19.5	12.7	1.6	0.7	0.2	0.1	-	0.1	-
1964	1275	4167	306	-	69.3	26.1	9.4	4.7	1.6	0.3	-	-	-	-
1965	1940	4199	462	-	23.7	62.4	53.0	4.2	5.0	1.1	1.2	-	0.1	-
1966	1811	6732	269	0.2	44.9	28.1	13.1	7.0	2.0	0.8	0.2	0.1	-	-
1967	1501	7080	212	-	16.6	22.2	14.1	6.2	3.8	2.3	0.8	0.5	-	-
1968	960	6575	146	0.2	20.7	12.9	12.0	6.2	1.3	0.3	0.2	-	-	-
1969	699	8738	80	0.2	7.5	8.2	7.2	2.0	1.6	0.6	0.4	0.1	-	-
1970	299	3987	75	0.1	15.5	10.8	3.1	1.1	0.3	0.2	0.1	-	-	-
1971	928	6874	135	0.7	29.4	5.9	3.6	3.7	2.3	1.5	0.3	0.2	-	0.2
1972	2320	9547	243	0.2	87.2	21.9	7.4	0.6	0.1	-	-	-	-	-
1973	1914	7250	264	0.3	15.4	29.6	45.2	1.3	0.7	2.5	-	-	0.7	-
1974	2292	11180	205	-	26.7	21.9	8.8	7.2	2.9	0.6	-	-	-	-
1975	2444	8341	293	0.3	69.0	41.8	13.3	4.9	0.4	1.2	-	0.2	-	-
1976	2271	10612	214	0.7	51.5	45.4	8.4	2.0	0.2	0.5	-	0.4	-	-
1977	1268	8234	154	0.9	64.8	22.5	6.3	2.2	0.8	0.4	0.3	-	-	-
1978	1959	7477	262	0.7	27.3	65.5	13.9	2.2	2.3	0.4	0.1	-	0.1	-
1979	1904	6974	273	1.1	83.3	19.8	11.9	5.5	-	0.4	-	-	-	-
1980	1335	6481	206	1.0	58.8	29.3	8.2	1.3	0.7	0.1	-	-	0.1	-
1981	858	4988	172	1.4	37.5	20.0	8.6	2.0	1.0	0.5	0.2	0.1	0.1	-
1982	603	5154	117	-	19.7	22.6	9.2	1.1	1.0	-	-	-	-	-
1983	183	6100	30	-	3.7	6.1	1.5	0.2	0.1	0.1	-	-	-	-
1984	382	5162	74	0.2	13.5	8.7	3.9	1.0	0.4	0.2	0.1	-	-	-
1985	299	4333	69	0.1	9.7	9.7	4.5	0.9	0.4	0.2	-	-	-	-
1986	241	4382	55	0.1	13.6	8.1	6.8	1.9	0.4	0.2	0.1	-	-	-
1987	3242	9649	336	1.2	195.0	9.9	2.0	1.0	0.3	-	-	-	-	-
1988	1859	6592	282	0.6	47.1	32.4	15.4	4.3	1.9	0.9	0.3	0.1	0.1	-

Table 3.7. Canada-U.S. annual nominal catch (landings), standardized equivalent effort, nominal CPUE and CPUE by age (number per hour), for Pacific cod from Hecate Strait (Areas 5C+5D), 1961-88.

Year	C-US Land (t)	C-US Eff (h)	C-US CPUE (kg/h)	Age									
				1	2	3	4	5	6	7	8	9	10
1961	1616	4391	368	-	21.5	140.6	60.5	11.2	2.0	1.1	1.1	-	-
1962	1690	2735	618	2.0	101.9	153.6	87.9	40.7	16.1	4.8	1.5	1.2	-
1963	2927	3157	927	14.7	170.8	378.7	190.4	60.0	10.4	12.0	3.8	1.6	0.1
1964	5228	3050	1714	1.9	469.9	290.9	122.9	52.8	9.4	1.6	0.5	0.3	-
1965	9119	5500	1658	0.5	58.3	425.2	178.8	39.1	10.9	0.8	0.9	0.1	-
1966	9519	6671	1427	1.1	66.1	228.9	167.9	46.4	11.9	1.6	0.2	0.1	0.1
1967	5112	4755	1075	-	200.1	142.7	86.7	38.4	14.3	4.6	1.3	0.2	0.1
1968	5165	14074	367	0.3	8.1	109.3	27.8	13.5	6.4	1.6	0.5	0.3	-
1969	2959	12078	245	0.2	36.7	24.4	35.0	13.2	3.4	1.8	0.2	0.1	0.1
1970	1339	8868	151	-	15.1	45.1	14.2	3.1	1.9	0.7	0.3	-	0.2
1971	1474	6856	215	0.8	70.4	24.0	15.7	7.9	1.1	0.7	0.5	-	-
1972	2694	4177	645	0.5	238.7	81.9	45.5	14.3	2.4	2.0	0.4	0.9	-
1973	4003	3552	1127	7.4	206.9	239.0	81.6	19.3	10.9	1.9	0.5	0.6	0.2
1974	4764	4630	1029	0.5	250.1	100.4	80.4	26.3	6.9	1.0	0.6	0.5	-
1975	4982	8649	576	0.1	68.3	107.0	42.1	21.6	2.6	4.2	1.7	0.8	0.1
1976	5016	10582	474	0.2	47.1	106.3	29.1	10.4	4.1	1.9	0.2	0.3	-
1977	3523	10124	348	0.1	93.3	54.3	27.3	5.1	3.2	1.0	-	-	-
1978	2102	5904	356	3.6	13.5	76.8	37.1	10.9	1.6	1.2	0.3	-	-
1979	4695	10274	457	0.7	133.6	34.1	44.6	10.5	3.3	0.6	0.3	-	0.1
1980	4540	12473	364	0.5	57.3	75.1	28.5	7.9	2.6	1.0	0.2	0.1	-
1981	3182	15752	202	0.9	26.0	28.2	28.1	9.9	1.4	0.9	-	-	-
1982	2077	5409	384	0.7	41.4	72.4	32.9	10.2	2.9	0.6	0.2	0.2	-
1983	2717	6967	390	0.3	32.9	63.3	37.4	12.8	3.0	0.9	0.2	-	-
1984	1748	5378	325	-	69.3	48.0	33.4	10.6	4.3	0.4	0.4	-	-
1985	1064	7093	150	0.4	10.7	30.9	10.6	3.7	1.9	0.2	0.1	-	-
1986	2099	3923	535	2.2	20.9	46.1	82.0	15.3	7.4	0.9	0.6	-	-
1987	8870	7870	1127	37.3	415.8	87.2	30.8	19.4	6.6	0.1	1.2	-	-
1988	6198	8525	727	1.2	62.4	202.7	65.3	12.5	2.6	1.2	0.1	-	-

Table 3.8. Virtual population analysis estimates of numbers-at-age (thousands) of Pacific cod from Hecate Strait (Areas 5C and 5D), for age classes 2-7, 1961-88. (Asterisks indicate estimates considered inaccurate -- cumulative F for year-class less than 2.0 -- Pope 1972.)

	Age					
Year	2	3	4	5	6	7
1961	6604	2592	962	1013	194	24
1962	9709	3548	986	336	521	100
1963	11342	5140	1640	367	105	255
1964	15869	5834	1964	478	69	34
1965	8137	7660	2570	807	148	18
1966	5654	4246	2550	715	289	39
1967	7864	2777	1248	608	174	102
1968	2768	3621	1037	392	202	47
1969	3466	1434	905	293	82	48
1970	4567	1577	578	199	51	17
1971	4966	2401	582	226	89	16
1972	7558	2372	1200	241	86	44
1973	5523	3419	1059	520	89	40
1974	5846	2493	1264	376	235	22
1975	6135	2374	1030	427	120	106
1976	4753	2953	647	309	102	50
1977	5649	2248	826	139	93	26
1978	4274	2419	840	256	40	28
1979	6723	2291	997	303	94	15
1980	3876	2706	1009	226	91	28
1981	3630	1607	824	304	54	27
1982	2779	1690	567	146	58	15
1983	3054*	1360	650	184	42	21
1984	4264	1509*	431	173	38	8
1985	3396*	2066	640*	110	54	5
1986	7226*	1811*	971	296*	42	20
1987	17487*	3911*	861*	304	119*	4
1988	5512*	7213*	1643*	298*	60	29*

Table 3.9. Virtual population analysis estimates of fishing mortality rate (F) for Pacific cod from Hecate Strait (Areas 5C and 5D), for age-classes 2-7, 1956-88.

	Age					
Year	2	3	4	5	6	7
1961	0.02	0.37	0.45	0.06	0.06	0.30
1962	0.04	0.17	0.39	0.56	0.12	0.19
1963	0.06	0.36	0.63	1.07	0.52	0.22
1964	0.13	0.22	0.29	0.57	0.76	0.21
1965	0.05	0.50	0.68	0.43	0.74	0.38
1966	0.11	0.62	0.83	0.81	0.44	0.46
1967	0.18	0.38	0.56	0.50	0.70	0.33
1968	0.06	0.79	0.67	0.97	0.84	0.97
1969	0.19	0.31	0.91	1.15	1.00	0.83
1970	0.04	0.40	0.34	0.20	0.55	0.61
1971	0.14	0.09	0.28	0.37	0.12	0.47
1972	0.19	0.21	0.24	0.39	0.16	0.29
1973	0.20	0.39	0.43	0.19	0.81	0.24
1974	0.30	0.28	0.49	0.54	0.20	0.32
1975	0.13	0.70	0.60	0.83	0.28	0.60
1976	0.15	0.67	0.94	0.60	0.78	0.73
1977	0.25	0.38	0.57	0.64	0.61	0.70
1978	0.02	0.29	0.42	0.40	0.38	0.41
1979	0.31	0.22	0.88	0.60	0.62	0.71
1980	0.28	0.59	0.60	0.83	0.62	0.86
1981	0.16	0.44	1.13	1.06	0.72	1.08
1982	0.11	0.36	0.53	0.66	0.43	0.37
1983	0.11	0.55	0.73	0.97	1.04	0.48
1984	0.12	0.26	0.77	0.56	1.38	0.37
1985	0.03	0.16	0.17	0.37	0.39	0.49
1986	0.01	0.14	0.56	0.31	1.87	0.27
1987	0.29	0.27	0.46	1.02	0.82	0.54
1988	0.14	0.38	0.58	0.62	0.63	0.59
Mean	0.14	0.38	0.58	0.62	0.63	0.59

Table 3.10. Virtual population analysis estimates of annual exploitation rate for Pacific cod from Hecate Strait (Areas 5C and 5D), for age-classes 2-7, 1956-88.

	Age					
Year	2	3	4	5	6	7
1961	0.01	0.24	0.28	0.05	0.05	0.20
1962	0.03	0.12	0.24	0.33	0.08	0.13
1963	0.05	0.23	0.37	0.52	0.31	0.15
1964	0.09	0.15	0.19	0.34	0.41	0.14
1965	0.04	0.31	0.38	0.27	0.41	0.24
1966	0.08	0.36	0.44	0.43	0.27	0.28
1967	0.12	0.24	0.33	0.30	0.39	0.21
1968	0.04	0.43	0.38	0.49	0.45	0.49
1969	0.13	0.21	0.47	0.55	0.50	0.44
1970	0.03	0.25	0.22	0.14	0.33	0.35
1971	0.10	0.07	0.18	0.24	0.08	0.29
1972	0.13	0.14	0.16	0.25	0.12	0.19
1973	0.13	0.25	0.27	0.13	0.43	0.17
1974	0.20	0.19	0.29	0.32	0.13	0.21
1975	0.10	0.39	0.35	0.44	0.18	0.35
1976	0.10	0.38	0.48	0.35	0.42	0.40
1977	0.17	0.24	0.33	0.37	0.35	0.39
1978	0.02	0.19	0.26	0.25	0.24	0.26
1979	0.20	0.15	0.46	0.35	0.36	0.39
1980	0.18	0.35	0.35	0.44	0.35	0.45
1981	0.11	0.28	0.54	0.51	0.40	0.52
1982	0.08	0.23	0.31	0.37	0.27	0.24
1983	0.07	0.32	0.40	0.49	0.51	0.29
1984	0.09	0.17	0.42	0.33	0.60	0.24
1985	0.02	0.11	0.12	0.24	0.25	0.30
1986	0.01	0.10	0.33	0.20	0.69	0.18
1987	0.19	0.18	0.28	0.50	0.44	0.32
1988	0.10	0.24	0.34	0.36	0.36	0.34
Mean	0.09	0.23	0.33	0.34	0.34	0.29

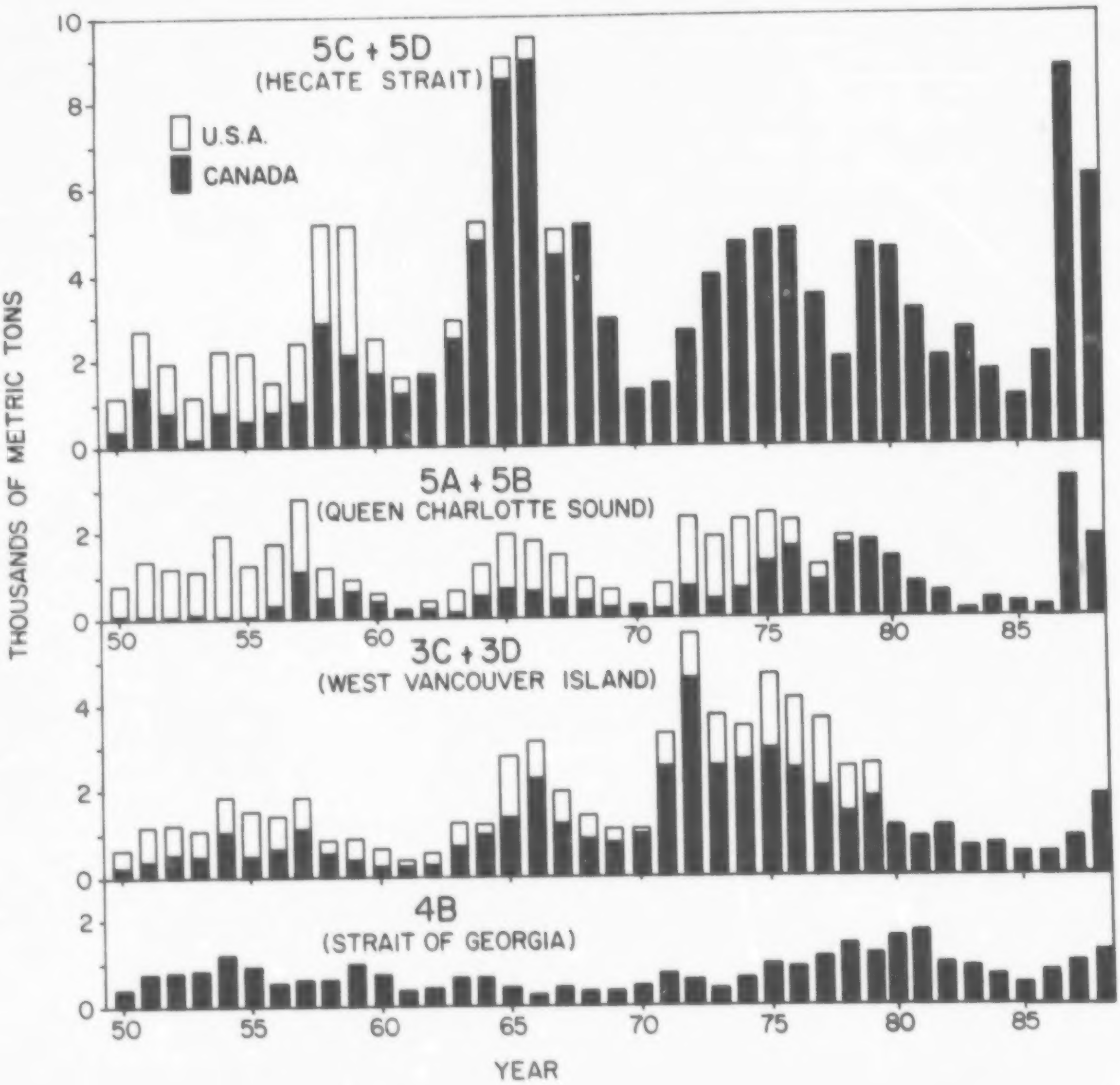


Fig 3.1. Canada-U.S. annual nominal catch (landings) of Pacific cod, by region, 1950-88.

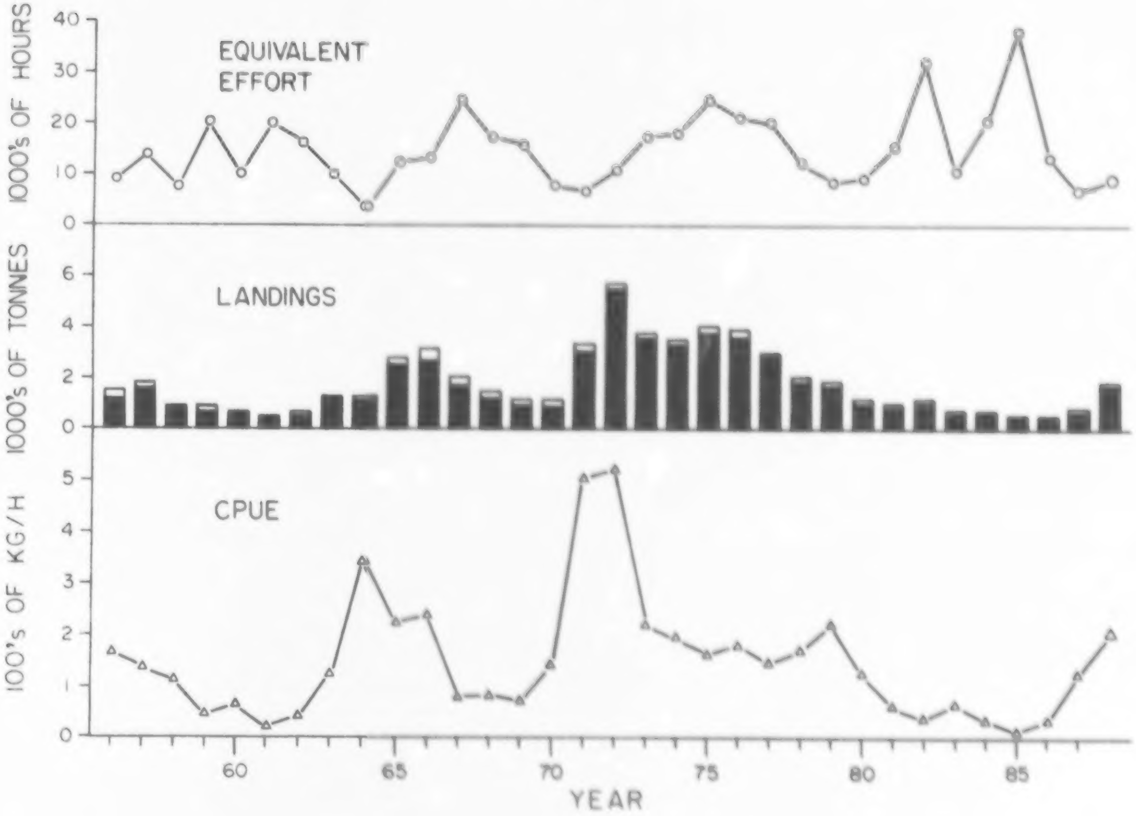


Fig. 3.2. Standardized Canada-U.S. landing statistics for Pacific cod from the west coast of Vancouver Island, 1956-88. Shaded portion of columns from Area 3C; clear portion from Area 3D.

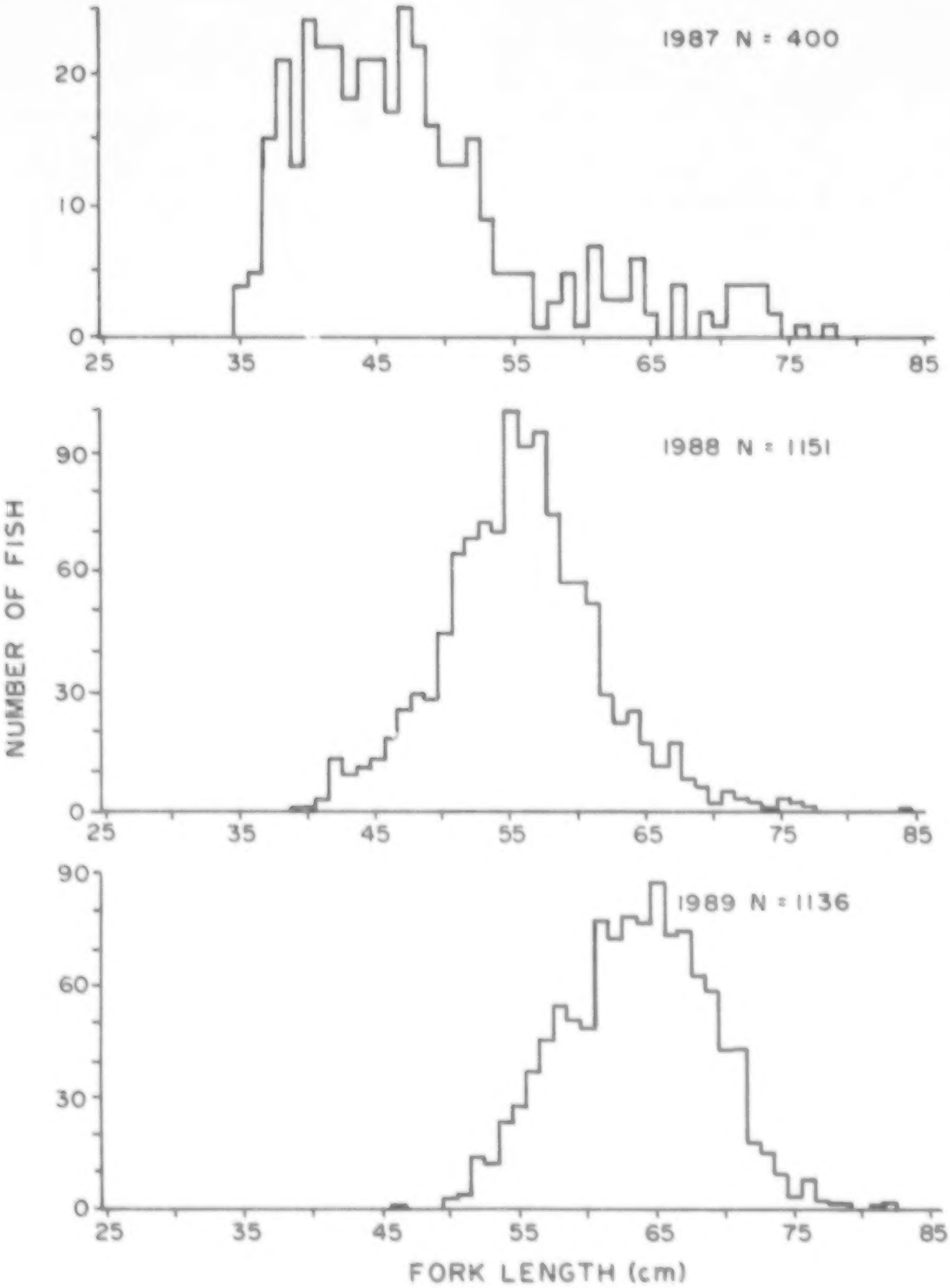


Fig. 3.3. Length frequency of Area 3C Pacific cod for the second quarter (April-June, inclusive) of 1987, 1988 and 1989. Number of fish measured by year (N) given in panels.

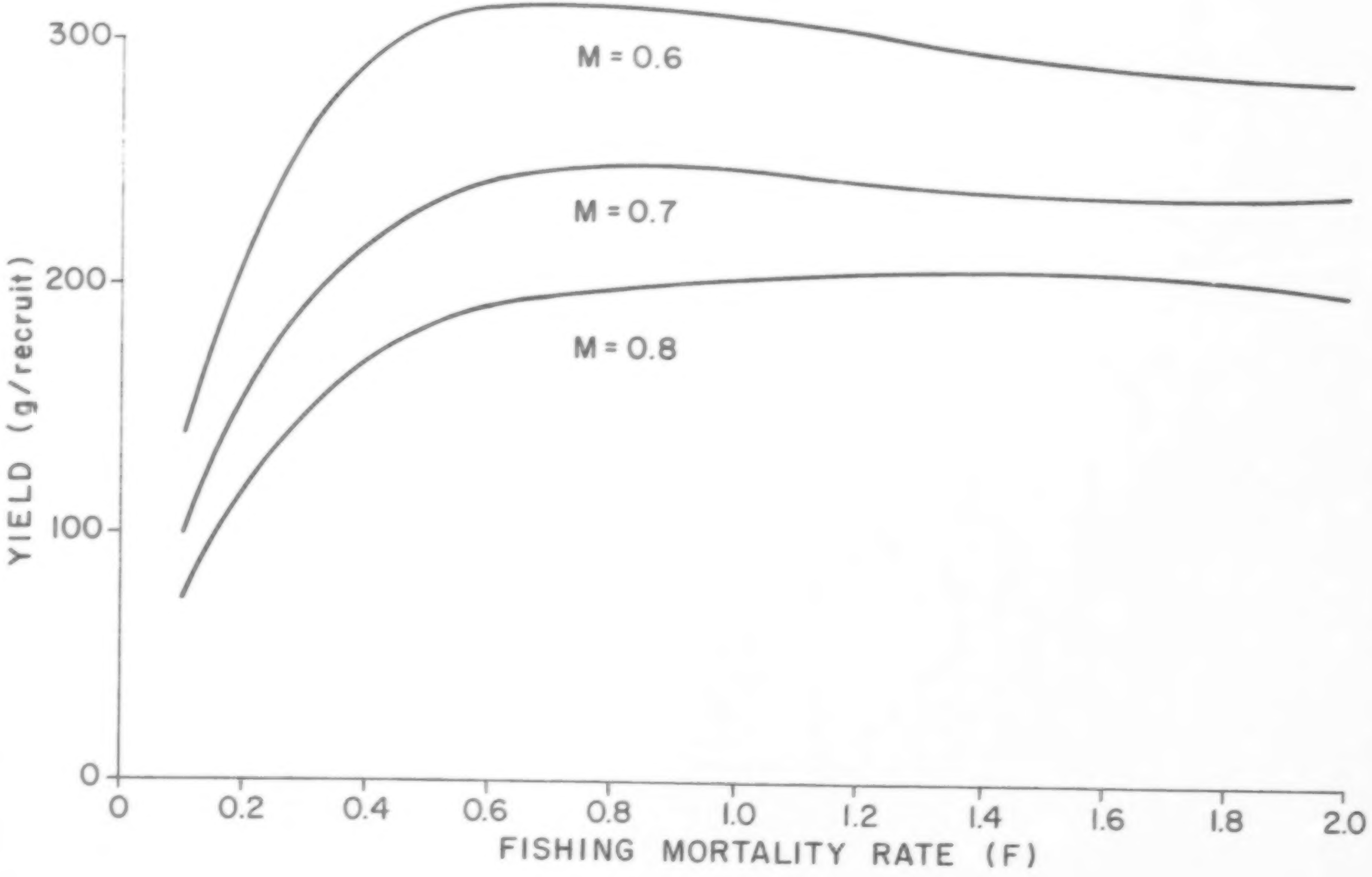


Fig. 3.4. Yield per recruit (g) vs fishing mortality rate (F) for Pacific cod from the west coast of Vancouver Island at three levels of M (0.6, 0.7 and 0.8), mesh size=5.3", and minimum commercial size=41 cm.

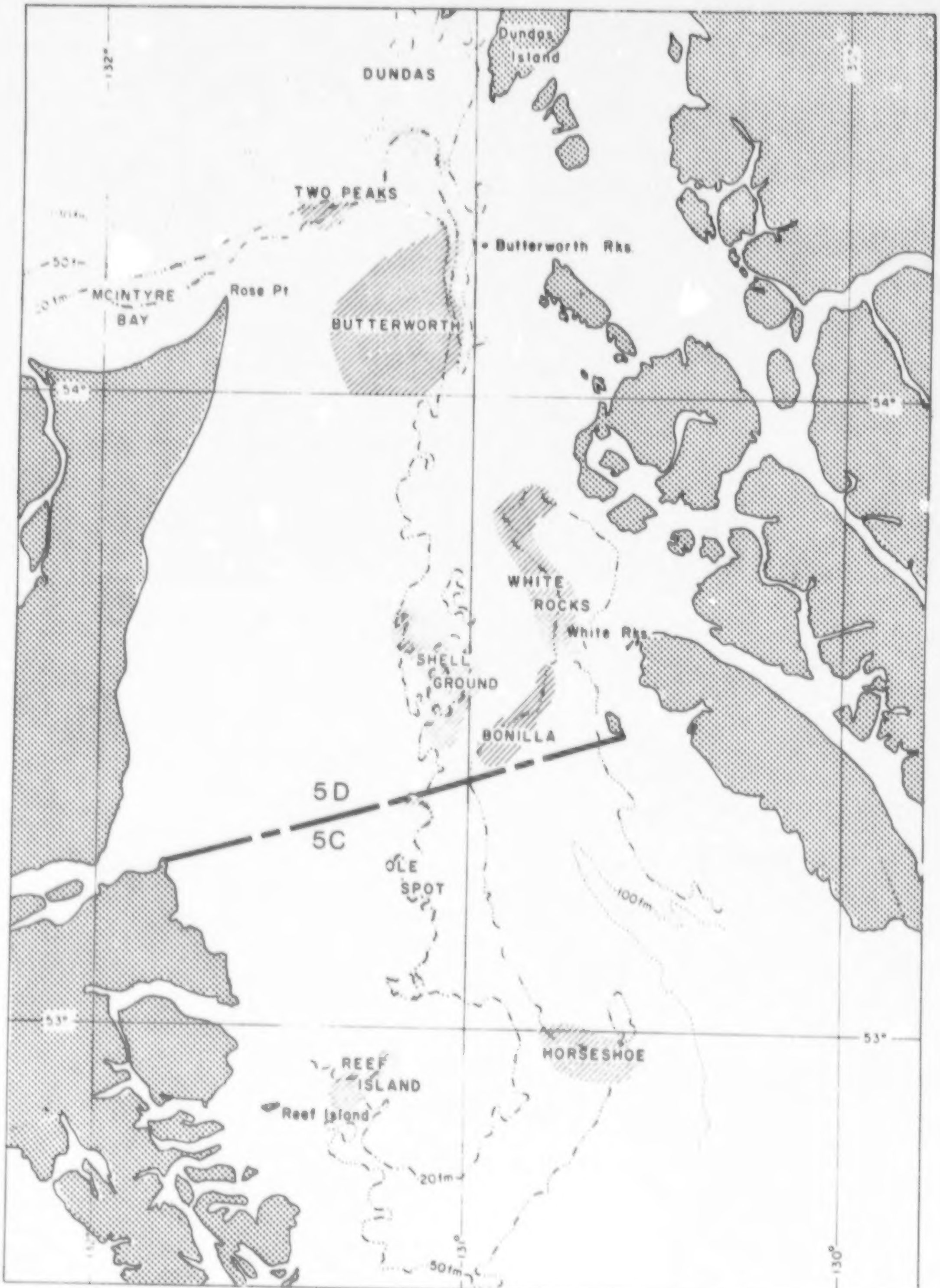

Dundas Island
DUNDAS
132°
TWO PEAKS
50fm
20fm
McINTYRE BAY
Rose Pt
Butterworth Rks.
BUTTERWORTH
54°
WHITE ROCKS
White Rks.
SHELL GROUND
BONILLA
5D
5C
OLE SPOT
100fm
53°
REEF ISLAND
Reef Island
HORSESHOE
20fm
50fm
131°
130°

Fig. 3.5. Important trawling grounds for Pacific cod in Hecate Strait.

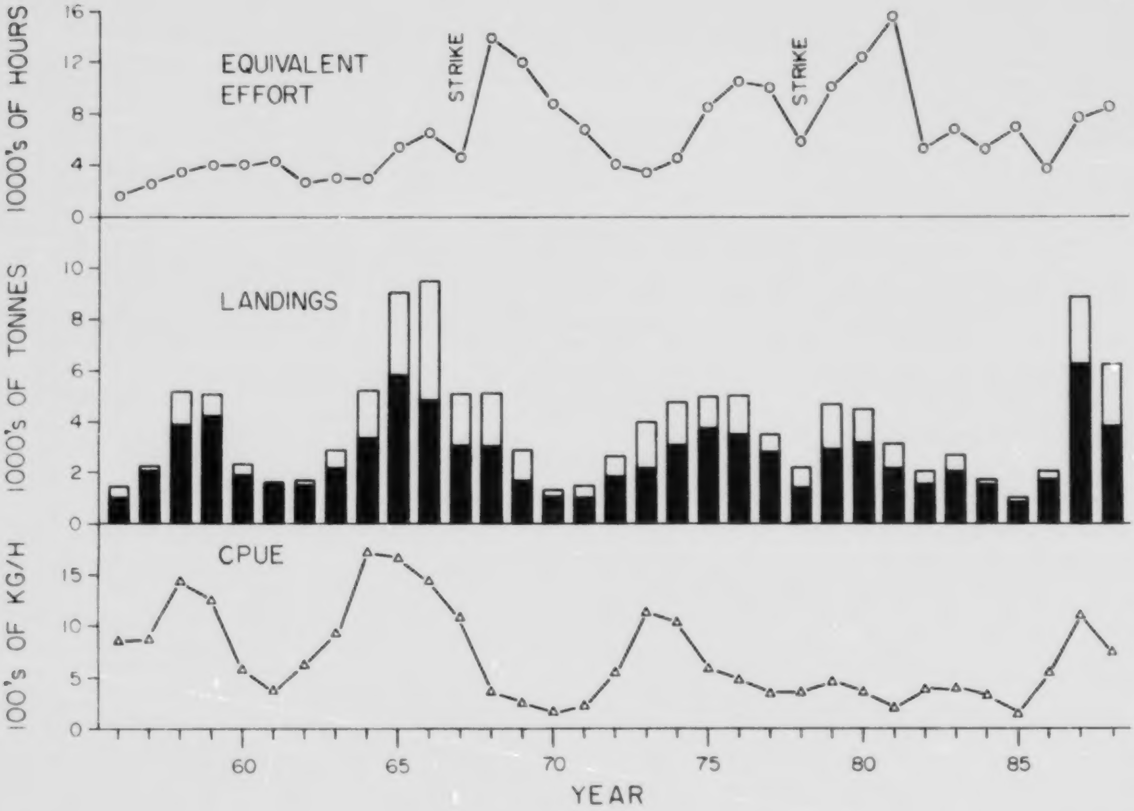


Fig. 3.6. Standardized Canada-U.S landing statistics for Pacific cod from Hecate Strait, 1956-88. Shaded portion of columns from Area 5D; clear portion from Area 5C. "Strike" indicates years when a component of the industry was on strike. This reduced the total effort for the year but did not influence CPUE.

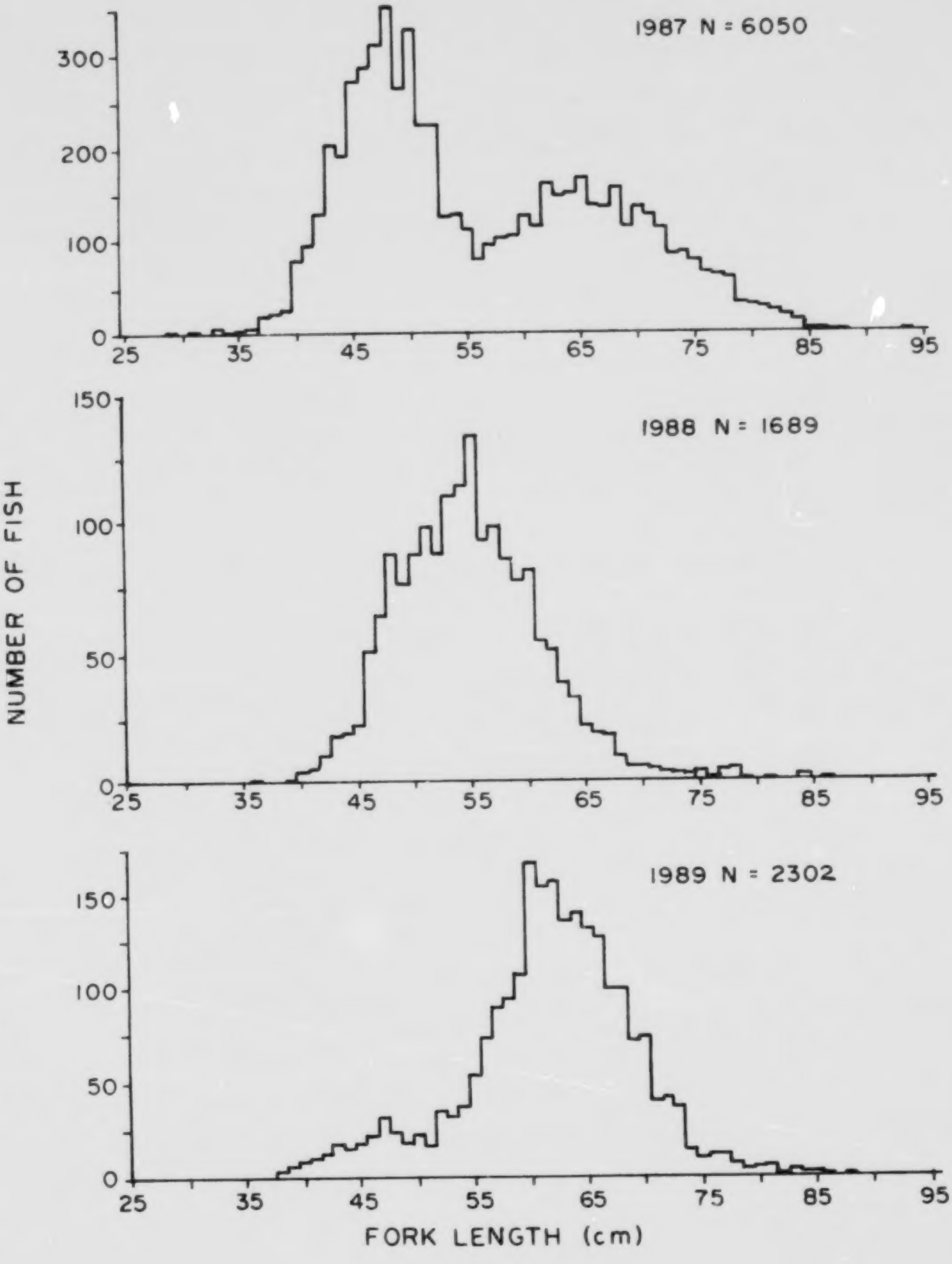


Fig. 3.7. Length frequency of Areas 5C and 5D Pacific cod for the first quarter (Jan.-March inclusive) of 1987, 1988 and 1989. Number of fish measured by year (N) given in panels.

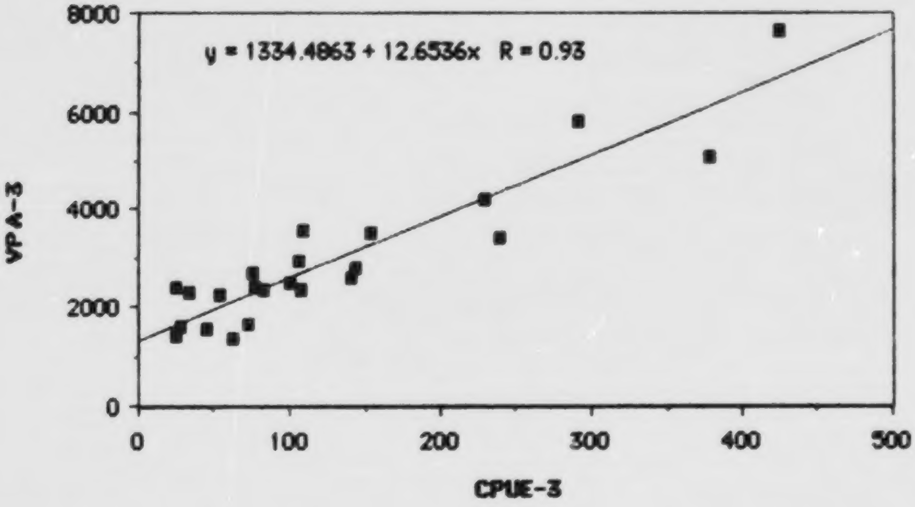


Fig. 3.8. Relationship between VPA estimates of numbers of age-3 fish (thousands) and nominal, standardized catch per unit effort of age-3 fish (number per hour) are fitted by linear regression. The r value shown is significant at the 5% level.

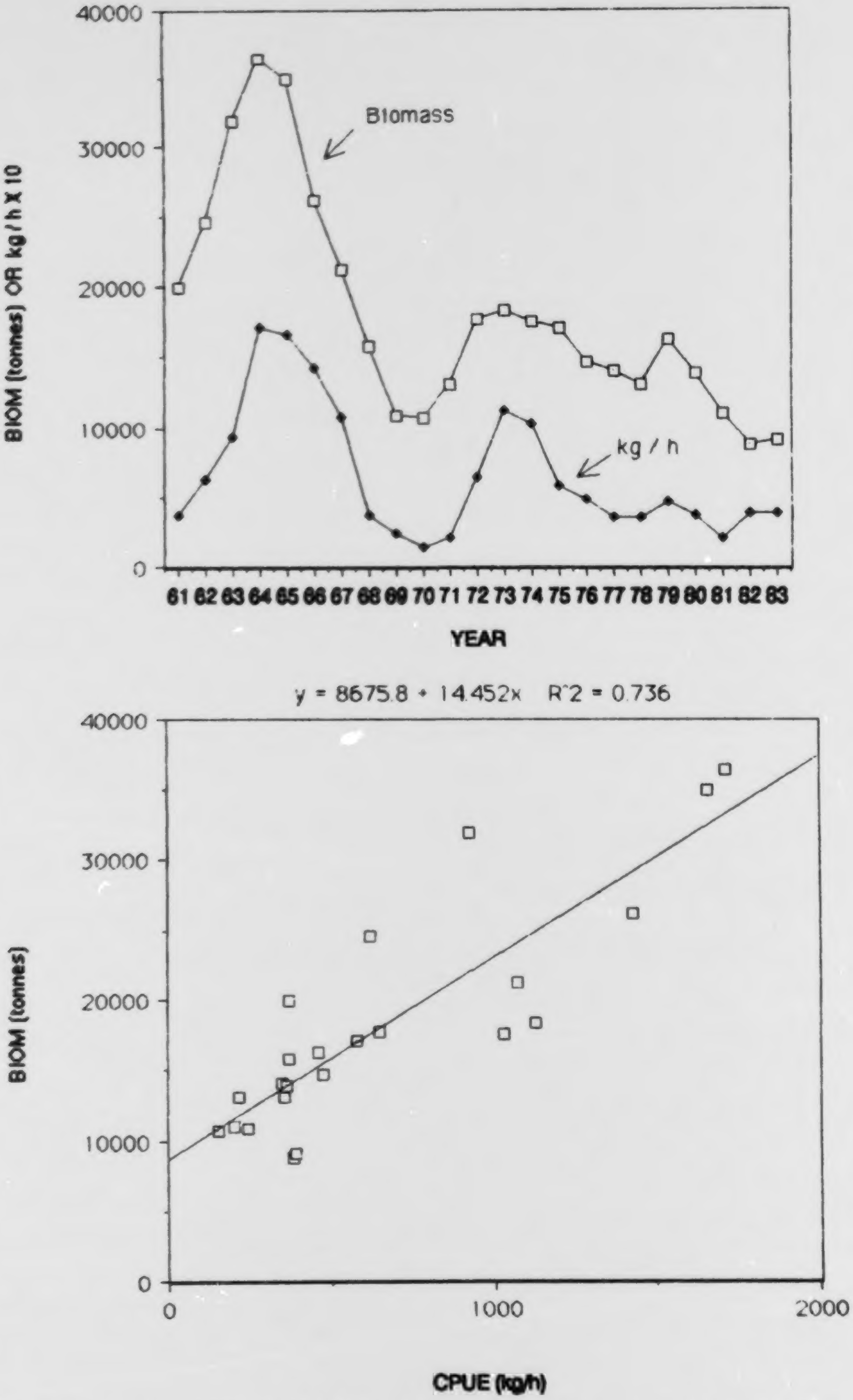


Fig. 3.9. Time series of VPA biomass (t) and nominal CPUE (kg/h) of the recruited stock biomass (top). Relationship between VPA estimates of stock biomass and CPUE, fitted by linear regression (bottom). Regression significant at the 5% level.

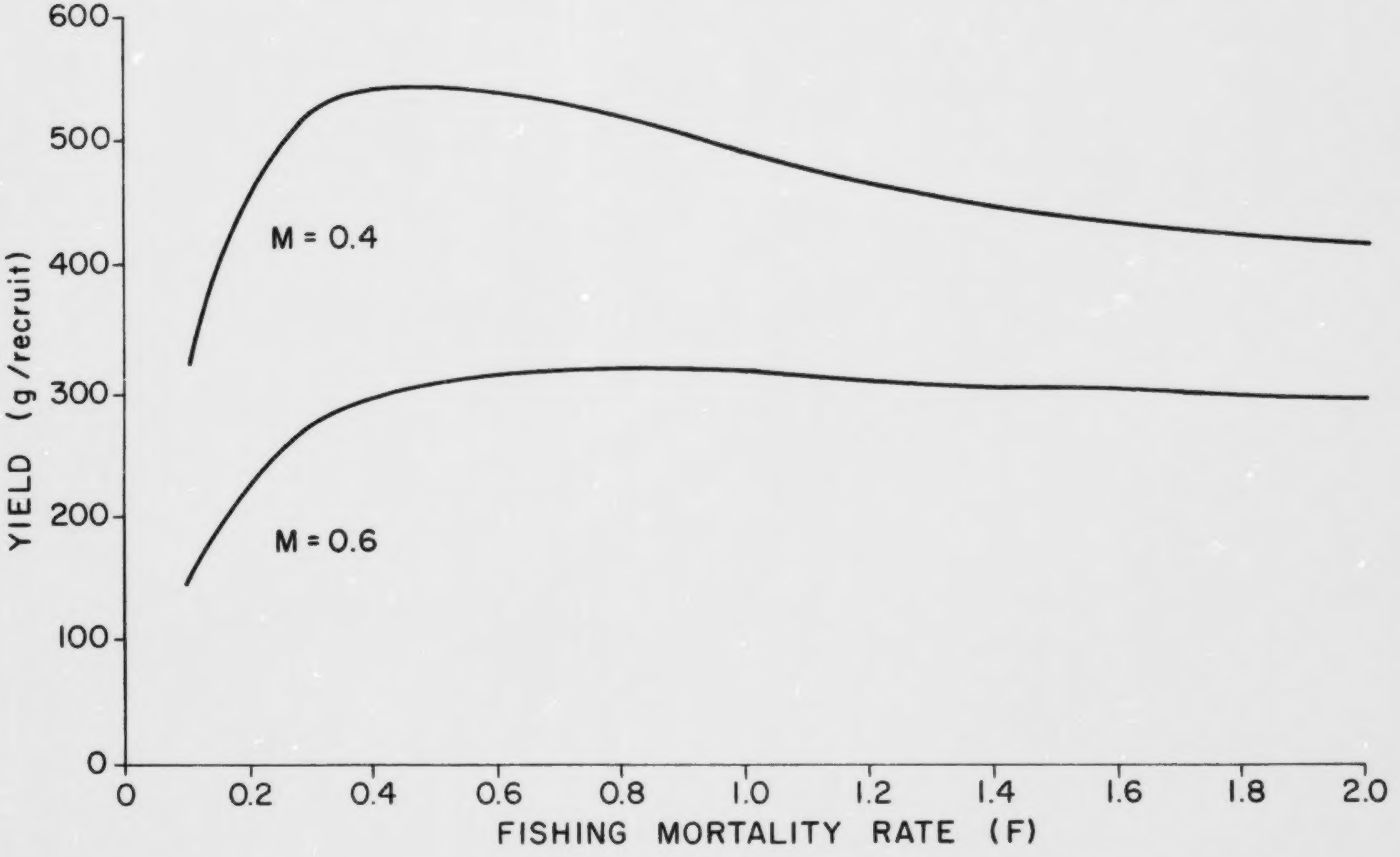


Fig. 3.10. Yield per recruit (g) vs fishing mortality rate (F) for Pacific cod from Hecate Strait at two levels of M (0.4 and 0.6), mesh size = 5.3", and minimum commercial size = 41 cm.

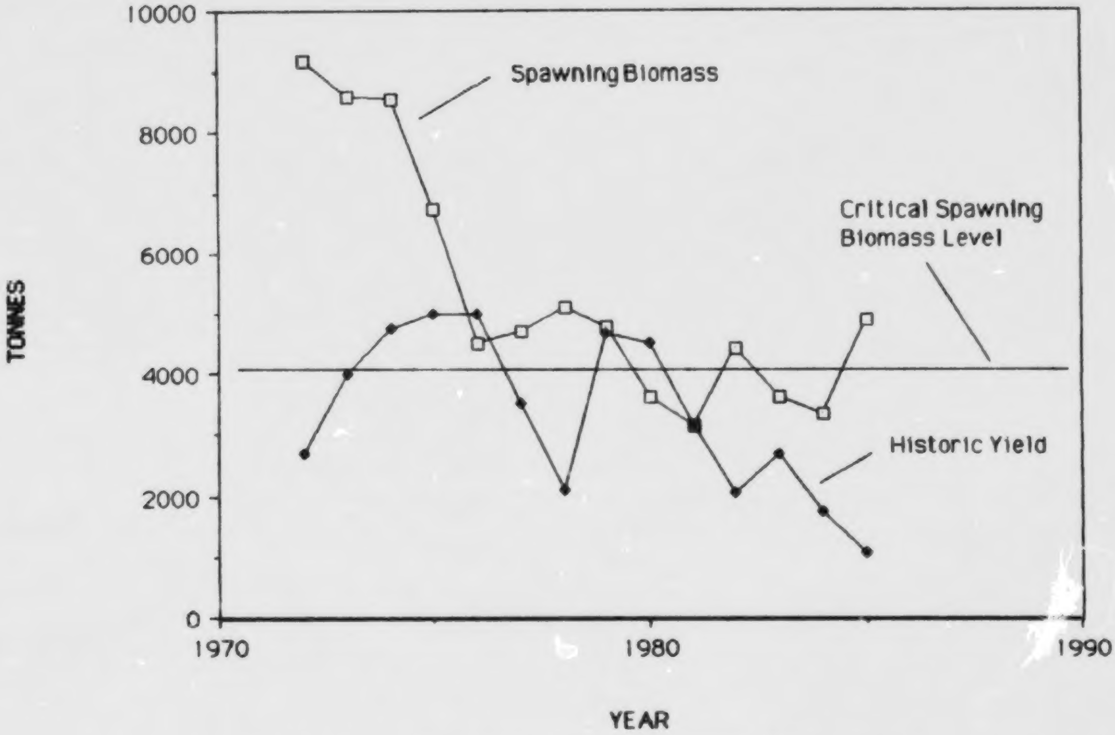


Fig. 3.11. Simulation analysis with estimated spawning biomass, critical spawning biomass, and historical yield.

4.0. FLATFISH

by J. Fargo

4.0.1. General Introduction

These stock assessments employ a variety of techniques, but they are they dependent on two basic types of data, 1) catch and effort and 2) biological data in the form of size and/or age composition. Time series for these data sets vary from 20-45 years depending on the species/stock. Because of the length of time that the landing statistics span, and changes in vessel efficiency, standardization is necessary in order to be able to make proper comparisons of the data among years. The standardization procedure is described, briefly, below.

Landing statistics, have been standardized to account for changes in CPUE due to increases in vessel horsepower. The standardization procedure involves the use of a multiplicative log-linear model which incorporates vessel horsepower effects on CPUE (Fargo 1989). The model does not fully account for increased fishing power over time. It only accounts for changes in fishing power due to changes in fleet composition relative to horsepower. It is similar to models used by Gavaris (1980) and Kimura (1981). The data are partitioned according to categories of year and horsepower class, and an index of relative CPUEs (standardized) is produced for each year. Standardized fishing effort is calculated by dividing landings for each year by the corresponding standardized CPUE. Landing statistics for rock sole assessments for Areas 5A, 5B, and 5C were standardized using this model for the first time. In past assessments, the option-2 method of Westrheim (1983) was used to assign fishing effort to species occupying similar area/depth time cells. CPUE was then standardized using relative fishing powers for vessel horsepower classes determined from a multiple species (rock sole, English sole, and Pacific cod) CPUE/horsepower relationship (Westrheim and Foucher 1985a). This method was abandoned because 1) Rock sole abundance with depth is not really consistent with that of English sole and Pacific cod, and 2) The CPUE/horsepower relationship for rock sole is different from the relationship used to assign relative fishing powers to vessel horsepower classes by Westrheim and Foucher (1985).

Estimates of sustainable yield in these assessments are produced from results of analysis of standardized landing statistics and yield per recruit analysis on an individual stock basis. Where possible, several independent abundance indices are used for monitoring the condition of stocks and estimating sustainable yields.

4.1. Coastwide

Yield options are not proposed for flatfish species on a coastwide basis.

4.2. Strait of Georgia

Yield options are not proposed for flatfish for this region.

4.3. West Coast of Vancouver Island

4.3.1. Petrale Sole

4.3.1.1. Introduction

The petrale sole (Eopsetta jordani) population off the west coast of Vancouver Island is thought to be composed of two stocks on the basis of tagging experiments conducted in the 1960s (Ketchen and Forrester 1966) (Pedersen 1975b). The "northern" stock occupies Areas 3D, 5A, 5B, 5C, and 5D while the "southern" stock occupies both the Canadian and U.S. portions of Area 3C.

4.3.1.2. Fishery

Analyses of Ketchen and Forrester (1966) and Pederson (1975a) have suggested that fishery effects on this species appeared to be overshadowed by environmentally induced variations in recruitment. The fishery for these stocks is now largely incidental in nature with a target fishery on spawning populations occurring during the first quarter of the year in the localities of Estevan Deep and Clayoquot Canyon.

4.3.1.3. Landing Statistics

Landings for the "southern" stock increased to 365 t in 1988 from 236 t in 1987 while landings for the "northern" stock increased to 576 t in 1988 from 303 t in 1987 (Tables 4.1,4.2 and Figures 4.1,4.2). The current landings are among the lowest recorded over the last 40 years.

4.3.1.4. Condition of the Stock

Petrale sole stocks off the west coast of Vancouver Island are considered to be at low levels of abundance. There were large removals from these stocks in the 1950s and 1960s and the decline in landings and, presumably, recruitment in the 1970s and 1980s may be the result of recruitment overfishing.

4.3.1.5. Yield Options

(1) Low risk-sustainable option: A 44,000 lb trip limit regulation for petrale sole is in effect, coastwide, from January 1-March 31. The January-March period corresponds to the spawning time for petrale sole, a period when these stocks are particularly vulnerable to exploitation. This regulation is aimed at reducing a target fishery on petrale sole while stocks

are depressed. The trip limit for petrale sole could be considered applicable only to the west coast of Vancouver Island rather than as a coastwide regulation.

(2) High risk-sustainable option: Previous analyses have suggested that petrale sole stock size has no effect on recruitment for the species and the trip limit could be removed and free-fishing allowed. As a caveat to this option, all previous analyses concerning stock and recruitment for the species were conducted when petrale sole stocks were at higher levels of abundance than they are at present. It is possible that recruitment overfishing has occurred. This hypothesis will require corroboration through updating the species age composition database and conducting virtual population analysis.

4.3.2. Dover Sole

4.3.2.1. Introduction

Dover sole (Microstomus pacificus) are found in commercial abundance along the Pacific coast from California to Alaska (Alverson 1960). They inhabit relatively shallow (50-80 fathom) depths over mud bottom during late spring-fall and migrate to deepwater (200-500 fathoms) offshore areas in winter for spawning. Abundance of this species has been shown to decrease with increasing latitude (Fargo et al. 1985). The largest stocks are found off California. Stocks off Oregon, and Washington are less abundant. In the late 1970s, Industrial Development Program exploratory fishing surveys (Harling et al. 1977, Harling et al. 1978) located a deepwater spawning concentration of Dover sole off the Queen Charlotte Islands. More recently, Pacific Biological Station research surveys have indicated a sizeable spawning population of Dover sole exists off the west coast of Vancouver Island (Carter et al. 1981). Survey catch rates for this species in Areas 3C and 3D were about 20% higher than catch rates in the IDP surveys off the west coast of the Queen Charlotte Islands in the late 1970s.

4.3.2.2. Fishery

The deepwater trawl fishery for Dover sole off the west coast of Vancouver Island began in the 1960s and 1970s, and involved, exclusively, U.S. trawlers. This fishery dissolved in 1978 with the advent of Canadian extended jurisdiction. In the early 1980s, with the increasing quota management of groundfish stocks off the west coast of Canada, Canadian fishermen became interested in harvesting new, non-quota stocks. Landings from the stock of Dover sole in Areas 3C and 3D are now significant enough to warrant assessment for the first time.

4.3.2.3. Landing Statistics

Canadian landing statistics were compiled for Areas 3C and 3D for the period 1980-88. U.S. landings from the Canadian portion of Area 3C and Area 3D prior to 1978 never exceeded 500 t, and no Effort-CPUE figures are available for this fishery. Canadian landings have averaged only 140 t from 1980-87 (Table 4.3). In 1988, landings were 514 t, more than a 200% increase from 1987. A preliminary estimate for 1989 landings is 1000 t. The low level of landings prior to 1988 precludes the use of landing statistics for assessment of this stock.

4.3.2.3. Condition of the Stock

With the limited nature of the fishery prior to 1988 the stock of Dover sole in Areas 3C and 3D could be close to virgin biomass. This is assuming that it is a separate stock from the Dover sole stock(s) off Washington state. The size of this stock is assumed to be intermediate to stocks off the coast of Washington State and the northwest Queen Charlotte Islands. The estimated MSYs for these two stocks are 2400 t and 800 t, respectively. Analysis of biological samples taken from this fishery for 1988 and 1989 will provide a somewhat more reliable picture of stock condition. It will be several years before fishery CPUE can be used to monitor the condition of this stock.

4.3.2.4. Yield Options

Low risk sustainable yield option -- A yield of 1000 t could be expected if the 3C-3D Dover sole stock is about 20% larger than the stock resident off the northwest Queen Charlotte Islands (survey catch rates for Dover sole off the west coast of Vancouver Island were 20% larger than off the Queen Charlotte Islands).

High risk sustainable yield option -- It is unlikely that this stock of Dover sole is larger than the Dover sole stock off the coast of Washington state. Therefore, 2000 t is considered to be an upper limit for yield at this time.

4.4. Queen Charlotte Sound

4.4.1. Rock Sole

4.4.1.1. Introduction to Area 5A

The rock sole (Lepidopsetta bilineata) is a minor component of the shelf, on-bottom trawl fishery in Area 5A. The Area 5A population is considered to be a separate stock on the basis of results of tagging experiments conducted in the 1950s and 1960s (Ketchen 1982). Other principal members of this multispecies fishery are Pacific cod (Gadus macrocephalus) and lingcod (Ophiodon elongatus). Rock sole are caught primarily in the 40-50 fathom depths of Cook Bank while Pacific cod and lingcod are caught in the 40-70 fathom depths. Standardized landing statistics are the basis for this assessment.

4.4.1.2. The Fishery

Landings from the multispecies fishery in Area 5A have been dominated by lingcod and Pacific cod. Most catches of rock sole are taken incidentally to these species. Fishery production for Area 5A rock sole is dependent upon recruitment, and recruitment has been highly variable over time. A trip limit regulation is the basis for management of rock sole in British Columbia. A coastwide trip limit of 30,000 lbs was in effect in 1989.

4.4.1.3. Landing Statistics

Standardized landing statistics were derived following the procedure outlined in Section 4.0.1 and Fargo (1989), and are presented in Table 4.4 and Figures 4.3., 4.4. Landings of rock sole in Area 5A increased to 128 t in 1988 from 80 t in 1987 while effort increased to 780 h in 1988 from 442 h in 1987. CPUE for rock sole in Area 5A decreased to 164 kg/h in 1988 from 181 kg/h in 1987. Pacific cod and lingcod continue to be the primary targets of this fishery.

4.4.1.4. Condition of the Stock

CPUE for Area 5A rock sole shows no trend over the last two decades. This is an indication that the rock sole stock in Area 5A has been at a stable level of abundance over this time period. Removals during this period ranged from 100-400 tonnes. Analysis of size composition catch rate data has indicated that the level of recruitment/abundance in 1987-88 is close to the average for the period 1966-87, but lower than the level which produced yields of 400 t in the late 1960s (Fargo 1989). Size composition catch rate data have also indicated that the level of recruitment was low for several years prior to 1987 (1980-86) (Fargo 1989). Thus overall stock size for Area 5A rock sole is probably relatively low. Spawning stock size has been shown to be an important factor in determining rock sole year-class production in Hecate Strait (Fargo and McKinnell 1989).

4.4.1.5. Yield Options

Low risk-sustainable yield option: A yield of 100 t is considered to be sustainable for the current stock abundance level. The 30,000 lb coastwide trip limit regulation for rock sole is consistent with this option.

High risk-sustainable yield option: Yields of 250 t are considered to be an upper limit for sustainable yield. This figure corresponds to a point midway between the yields for high and low recruitment levels determined from size composition catch rate data.

4.4.1.6. Introduction to Area 5B

Rock sole is a minor component of the multispecies shelf, on-bottom trawl fishery in Area 5B. The Area 5B population is considered to be a separate stock on the basis of results of tagging experiments conducted in the 1950s and 1960s (Ketchen 1982). Pacific cod and lingcod are the major components in this multispecies fishery. Standardized landing statistics are the basis for this assessment.

4.4.1.7. The Fishery

Catches of rock sole in Area 5B have traditionally come from the 40-50 fathom depth range on the outer edges of Goose Island Bank, which is considered to have good "trawlable" bottom. There has been speculation among fishermen over the years that rock sole occupy the top of the bank (10-39 fathom depths) which is composed mainly of rough bottom type, not amenable to trawl capture of flatfish. One reason for this speculation is that suitable habitat is available for rock sole on top of the bank, and rock sole in other areas along the Pacific coast are most abundant at shallower (10-39 fathom) depths. Fishery production for Area 5B rock sole is dependent upon recruitment and recruitment has been highly variable over time. A trip limit regulation is the basis for management of the rock sole fishery in British Columbia. A coastwide trip limit of 30,000 lbs was in effect in 1989.

4.4.1.8. Landing Statistics

Standardized landing statistics were derived following the procedure outlined in Section 4.0.1 and Fargo (1989), and are presented in Table 4.5 and Figures 4.5, 4.6. Landings increased to 272 t in 1988 from 205 t in 1987, while effort increased to 971 h in 1988 from 840 h in 1987. CPUE for 1988 was 280 kg/h, the highest in the time series. There is no long-term trend in CPUE (1956-88). Over the last three years, there has been an upward trend in CPUE. Short term trends observed in CPUE coincide with recruitment fluctuations determined from size composition catch rate data for the species.

4.4.1.9. General Biological Information

There were no samples collected in 1988 for Area 5B rock sole. Size composition catch rate data for 1986-87 indicated that there was a significant increase in recruitment in those years (1985 year-class) (Fargo 1989). We assume that recruitment is still strong because of the strong 1985 year-class.

4.4.1.10. Condition of the Stock

On the basis of recent trends in CPUE, the Area 5B stock is considered to be at an above average level of abundance. CPUE has been increasing over the last three years with removals of approximately 200 t annually, and removals as high as 600 t in the past do not appear to have produced any lasting effect on CPUE. However, size composition catch rate data indicates that recruitment was at fairly low levels for several years prior to 1987. Thus overall stock size is probably not as high as stock sizes that produced yields of 600 t in the past. Size of the spawning stock has been shown to be an important factor in the production of rock sole year-classes in Hecate Strait (Area 5D).

4.4.1.11. Yield Options

Low risk-sustainable yield option: A yield of 200 t is considered to be sustainable for the Area 5B stock. The coastwide 30,000 lb trip limit for rock sole is consistent with this option.

High risk-sustainable option: 400 t is the high-risk sustainable figure estimated for the Area 5B rock sole stock. This figure corresponds to a point midway between the yields for high and low recruitment levels (late 1960s and early 1980s, respectively).

4.5. Hecate Strait

4.5.1. Rock Sole

4.5.1.1. Introduction to Area 5C

The rock sole is one component in a multi-species on-bottom trawl fishery in Hecate Strait along with English sole (Parophrys vetulus) and Pacific cod. The Area 5C rock sole stock has been defined using abundance trends from landing statistics, size composition analysis and results of a 1982 tagging experiment (Fargo and Westrheim 1987). Standardized landing statistics are the basis for this assessment.

4.5.1.2. Fishery

The fishery for rock sole in Area 5C is seasonal. The majority (80%) of the landings occur during April-September. The spring fishery is predominantly on a spawning population at Reef Island-Cumshewa grounds while summer and fall landings come from the multispecies trawl fisheries at Horseshoe and Ole Spot grounds. A trip limit regulation is the basis for management of the rock sole fishery. A coastwide trip limit of 30,000 lbs was in effect in 1989.

4.5.1.3. Landing Statistics

Standardized landing statistics were derived following the procedure outlined in Section 4.0.1 and Fargo (1989), and are presented in Table 4.6 and Figures 4.7, 4.8. Landings decreased to 189 t in 1988 from 209 t in 1987. CPUE for rock sole in Area 5C decreased to 291 kg/h in 1988, from 354 kg/h in 1987. Effort increased to 649 hours in 1988 from 590 hours in 1987. No longterm trend is apparent in CPUE. Short term trends observed in CPUE coincide with fluctuations in recruitment/abundance as determined from size composition catch rate data. Fishing effort in 1988 was only about half the longterm average for the period 1956-88.

4.5.1.4. Condition of the Stock

The Area 5C rock sole stock is considered to be at an average/above average level of abundance based on trends in standardized CPUE. It was also noted in Fargo (1989) that recruitment for Area 5C rock sole had increased significantly in 1987-88, based on size composition catch rate data. The 1988 catch rate for age 4-5 fish (length range = 30 to 40 cm) was 118 fish/hr. The average comparable catch rate for 1977-1979=116 fish/hr.

4.5.1.5. Yield Options

Low risk-sustainable yield option -- A yield of 500 t is equivalent to the average yield during 1977-79, when catch rates of age 4-5 fish (recruits) were similar to 1988 catch rates. A trip limit of 30,000 lbs is consistent with this option.

High risk-sustainable yield option -- A yield greater than 600 t in 1979 was associated with a subsequent decline in CPUE. Therefore, yields of 600 t are considered to be an upper limit of sustainable yield for the Area 5C stock at this time.

4.5.1.6. Introduction to Area 5D

The rock sole population in Area 5D is one of the most intensively studied marine fish populations in British Columbia (Forrester and Thomson 1969; Stocker 1981; Fargo and McKinnell 1989). For the past 40 years the stock has been characterized by cyclic abundance trends attributed to fluctuations in recruitment (Fargo 1989). Large year-classes have been produced by this stock about once a decade since monitoring began in the late 1940s. Ocean temperature at the time of spawning (temp.

optimum=6.3°C) and stock size (critical stock size ≈ 3,000,000 spawning females) have been suggested as important factors in determining year-class production for the stock (Fargo and McKinnell 1989). Standardized landing statistics and yield per recruit analysis are the basis for this assessment.

4.5.1.7. The Fishery

The fishery for rock sole in Area 5D is mainly a seasonal one. The majority (80%) of the landings occur during the months April-September. Principal fishing grounds are Two Peaks and Butterworth. Area 5D rock sole occupy depths of 10-40 fathoms, but are most concentrated at 10-29 fathoms. They are also caught incidentally to Pacific cod and English sole at 30-49 fathoms. Fishery production for the Area 5D stock is dependent upon recruitment and recruitment has been highly variable over time. A trip limit regulation is the basis for management of the rock sole fishery in British Columbia. A coastwide trip limit of 30,000 lbs is in effect in 1989.

4.5.1.8. Landing Statistics

Standardized landing statistics were derived following the procedure outlined in Section 4.0.1. and Fargo (1989), and are presented in Table 4.7 and Figures 4.9,4.10. Landings in 1988 were 1213 t up from 327 t in 1986. CPUE decreased to 478 kg/h in 1988 from 1020 kg/h in 1987. The level of effort in 1988 was 2538 h, up from 321 h in 1987.

4.5.1.9. Yield per Recruit Analysis

A yield per recruit analysis was conducted for Area 5D rock sole. This analysis differed from the yield per recruit analysis in Fargo (1988) in the maximum age used for yield per recruit calculations. Anthony (1982) stressed the importance of using an adequate value of maximum age attained rather than the maximum age observed in the current fishery. The maximum age used for these calculations was 20 while the maximum age for the previous calculations was 10. Results indicate that a yield of 476 grams/recruit is achieved at a fishing rate of 0.23 (equivalent to $F_{0.1}$). The previous yield per recruit analysis indicated $F_{0.1}=0.38$ with a corresponding yield of 489 grams/recruit. The present level of recruitment is considered to be similar to the level of recruitment during the late 1970s (Fargo 1989). The $F_{0.1}$ (in the case of this species/stock, $F_{0.1}=M$) yield was calculated using the following procedure. The average level of recruitment from 1975-79 was calculated at 1,475,000 females from results of virtual population analysis (Fargo 1989). This figure was multiplied by the figure of 476 grams/recruit and assuming that females comprise approximately 70% of the landings by weight, divided by 0.7 to produce an estimate of 1003 t for an $F_{0.1}$ harvest level.

4.5.1.10. Condition of the Stock

Recruitment for the rock sole stock in Area 5D has increased significantly over the last two years based on analysis of standardized landing statistics and size composition catch rate data (Fargo 1989). The current level of recruitment is thought to be equivalent to the level in the late 1970s (Fargo 1989).

4.5.1.11. Yield Options

Low risk-sustainable yield option -- The estimated $F_{0.1}$ (F=M) yield for the present level of recruitment was exceeded by 20% in 1988. A low risk-sustainable yield of 700 t (a figure intermediate to 1987-88 landings) is suggested to help offset any decline in abundance of Area 5D rock sole due to overharvesting in 1988. The coastwide trip limit of 30,000 lbs did not prevent overharvesting of this stock in 1988. A trip limit of 20,000 lbs or 30,000 lbs with a limit of two trips per vessel per month would probably help to alleviate this situation. This would also result in the underharvesting of rock sole stocks in all other areas if the regulation is applied on a coastwide basis.

High risk-sustainable yield option -- The results from yield per recruit analysis indicate that yields of 1000 t are sustainable for the current level of recruitment. A risk is associated with this figure because of the fact that the rock sole stock in Area 5D has been at low levels for nearly a decade. Spawning stock size has been shown to be an important determinant of year-class production and presumably is important to longterm survival for the stock.

4.5.2. English Sole -- Hecate Strait

4.5.2.1. Introduction

English sole in Hecate Strait have been treated as a single stock for this assessment. In the past, only English sole in Area 5D were assessed. Preliminary results of a tagging experiment conducted in 1983 indicate that English sole in Hecate Strait can be treated as a single stock. Managers have indicated that, for the purpose of enforcement, a single catch regulation for English sole in Hecate Strait is desirable. Standardized landing statistics, virtual population analysis, and yield per recruit analysis are the basis for this assessment.

4.5.2.2. The Fishery

The principal fishing grounds for English sole are Two Peaks-Butterworth (April-September) and White Rocks (October-March). Approximately 80% of the landings come from the former. Most landings of this species are incidental to those of

Pacific cod which occupies similar depth ranges and areas. The majority of the harvest is composed of females aged 4-10 years (most males do not attain legal commercial size). A significant amount of 3-year-old fish may be discarded as undersized in this fishery as well. Presumably, mortality for these fish is extremely high. Fishery production for the species is dependent upon recruitment, with recruitment being highly variable (coefficient of variation = 100%) over time.

4.5.2.3. Landing Statistics

Landing statistics for English sole in Hecate Strait have been standardized, as in previous assessments, using the option-2 method of Westrheim (1983) and standardization procedure of Westrheim and Foucher (1985a). They are presented in Table 4.8 and Figures 4.11, 4.12. Landings of English sole in 1988 were 688 t, up from 630 t in 1987. CPUE for 1988 was 268 kg/h up from 132 kg/h in 1987 and above average for 1956-88. Effort was down 82% to 2567 h in 1988, probably as a result of the fishery for Pacific cod being less intensive in 1988 than in 1987. CPUE shows no overall trend since the mid-1960s. Short term fluctuations in CPUE coincide with recruitment/abundance fluctuations for the species determined by virtual population analysis.

4.5.2.4. Virtual Population Analysis

Virtual population analysis (VPA) results are presented in Tables 4.9,4.10. The catch-at-age data were standardized to account for differences in ageing techniques over time. Recruitment estimates are considered to be reliable only through 1973. This is because the cumulative fishing mortality for cohorts after that year is less than 2.0 (Pope 1972). Because of the lack of recruitment data for years after 1973, forward simulations using VPA results from this analysis must be interpreted with caution. Updating of the age composition database for English sole is not expected in the coming year.

4.5.2.5 Yield per Recruit Analysis

Results from yield per recruit analysis indicate that a yield of 239 grams/recruit is achieved with a fishing rate of 0.21 (equivalent to $F_{0.1}$ and roughly equivalent to M for the species), with recruitment at age 3. The maximum age used for these calculations was 20. A previous yield per recruit analysis, where maximum age was 10 estimated $F_{0.1}$ at 0.31 with a corresponding yield of 241 grams/recruit. The average level of recruitment from the last reliable years (1971-73) in the virtual population analysis was 2,184,000 females. Size composition catch rate data previously indicated that the current level of recruitment is similar to the level in the mid-1970s (Fargo 1989). A yield of 700 t was computed for an $F_{0.1}$ harvest level using the following procedure. The average recruitment for 1971-73 was multiplied by 239 grams/recruit and this result was divided by 0.7, the estimated proportion by weight of females caught in the fishery. The yield per recruit analysis also indicated that yield can be increased by 30% if the age of recruitment for the species is 4 rather than 3.

4.5.2.6. Condition of the Stock

On the basis of trends in CPUE in recent years and size composition catch rate data (Fargo 1989), the Hecate Strait English sole stock is considered to be at average levels and increasing due to increasing recruitment (Fargo 1989). However, age of recruitment is below the age where maximum yield was obtained in the yield per recruit analysis.

4.5.2.7. Yield Options

Low risk-sustainable yield option -- Yields of 700 t are sustainable with recruitment at current levels with the current age of recruitment. As a caveat, this figure could be increased to 900 t if the age of recruitment could be increased, for example, by regulating mesh size.

High risk-sustainable yield option -- Yields of 800 t could be sustainable if the trend of increasing recruitment continues in 1990.

4.5.3. Dover Sole

4.5.3.1. Introduction

The last detailed stock assessment for Dover sole is contained in Fargo (1989). As in the past, estimates of yield for this assessment are determined by surplus production analysis of standardized catch/effort data.

4.5.3.2. The Fishery

The fishery for Dover sole takes place at depths of 50-80 fathoms at Butterworth, Two Peaks, and Dundas grounds in northern Hecate Strait (May-October) and 100-200 fathoms at Langara Deep and Frederick Island (December-April) off the west coast of the Queen Charlotte Islands. The seasonal shift in the fishery is related to the annual bathymetric migrations Dover sole undergo for the purpose of spawning.

4.5.3.3. Landing Statistics

Standardized landing statistics for Dover sole for 1970-87 are presented in Table 4.12 and Figures 4.13,4.14. CPUE for Dover sole was standardized using the procedure outlined in

Section 4.0.1 and Fargo (1989). The CPUE time series shows a declining trend from 1970-79, probably an initial fishing up phase. An upward trend in CPUE is also observed from 1980-88. Landings in 1988 increased to 649 t from 503 t in 1987. Effort increased to 941 h in 1988 from 490 h in 1987, but is below average for the period 1970-88.

4.5.3.4. General Biological Information

Annual size composition data compiled from 1970-88 indicate no change in mean length and no observable change in the overall size composition over this time period.

4.5.3.5. Condition of the Stock

The trend in CPUE from 1979-88 indicates that the 5CDE Dover sole stock is increasing in abundance (with average annual removals of 800 t), although the 1988 CPUE observation is down from 1987. MSY estimated from standardized effort and CPUE using Gulland's (1961) method is 836 t, while the optimum effort level is estimated at 880 h using a lag period of 3 years.

4.5.3.6. Yield Options

Low risk-sustainable option -- Yields of 800 t are sustainable for the Area 5CDE Dover sole stock.

High risk-sustainable option -- Based on analysis of recent trends in CPUE (Fargo 1989) a yield of 1000 t can be considered to be sustainable with some risk.

Table 4.1. Canada-U.S. landings (t) of petrale sole from southwest Vancouver Island (Area 3C)--the area occupied by the "southern stock" 1942-88.

Year	Flattery Spit	Northern section Area 3C	Total Area 3C	Year	Flattery Spit	Northern section Area 3C	Total Area 3C
1942	?	-	1561	1966	118	512	630
1943	?	-	2264	1967	106	259	365
1944	?	-	1489	1968	114	233	347
1945	?	-	718	1969	255	142	397
1946	?	-	906	1970	80	198	278
1947	?	-	627	1971	74	523	597
1948	?	-	1321	1972	22	561	583
1949	?	-	1178	1973	211	452	663
1950	?	-	854	1974	230	684	914
1951	?	-	794	1975	474	465	939
1952	?	-	948	1976	304	453	757
1953	?	-	748	1977	157	311	468
1954	?	-	664	1978	287	126	413
1955	?	-	415	1979	256	92	348
1956	40	585	625	1980	147	115	262
1957	9	629	638	1981	125	180	305
1958	19	609	628	1982	45	232	277
1959	33	1072	1105	1983	179	183	362
1960	233	974	1207	1984	237	218	455
1961	375	1109	1484	1985	122	147	269
1962	215	850	1065	1986	75	197	272
1963	90	658	748	1987	113	123	236
1964	71	530	601	1988	182	183	365
1965	140	658	798				

Table 4.2. Canada-U.S. landings (t) of petrale sole from the "northern stock" Areas 3D,5A-5D, 1942-88.

Year	Area 3D	Areas 5A-5B	Areas 5C-5D	Total
1942	-	-	-	-
1943	-	-	-	-
1944	499	303	-	802
1945	270	1535	193	1998
1946	623	1258	494	2375
1947	469	986	769	2224
1948	943	920	3011	4874
1949	316	429	1644	2390
1950	694	569	700	1963
1951	305	326	642	1273
1952	265	305	574	1144
1953	235	450	46	731
1954	712	234	300	1237
1955	452	462	94	1008
1956	291	528	53	872
1957	1320	333	216	1869
1958	174	227	171	572
1959	227	160	216	603
1960	93	212	120	425
1961	277	171	102	550
1962	295	343	165	803
1963	202	537	82	821
1964	183	421	163	767
1965	300	418	202	920
1966	264	469	260	993
1967	169	485	176	830
1968	293	266	137	696
1969	262	114	22	398
1970	136	56	22	214
1971	127	97	55	280
1972	50	154	33	237
1973	197	211	24	432
1974	196	283	14	493
1975	234	156	27	417
1976	153	132	30	315
1977	58	73	24	155
1978	21	63	13	97
1979	10	57	39	106
1980	31	40	33	104
1981	15	41	42	98
1982	30	61	16	107
1983	29	161	35	225
1984	77	79	24	180
1985	50	81	22	153
1986	24	120	25	169
1987	37	165	101	303
1988	276	167	133	576

Table 4.3. Canadian landings of Dover sole from International Areas 3C and 3D, 1980-88.

Year	Landings (t)
1980	277
1981	255
1982	200
1983	98
1984	99
1985	76
1986	77
1987	38
1988	514

Table 4.4. Standardized Canada-U.S. landing statistics for rock sole from Area 5A, January-December 1956-88.

Year	Landings (t)	Effort (h)[a]	CPUE (kg/h)[b]
1956	551	2505	220
1957	511	2212	231
1958	501	2738	183
1959	212	926	229
1960	397	2046	194
1961	237	1145	207
1962	196	1181	166
1963	161	875	184
1964	156	719	217
1965	157	633	248
1966	330	1264	261
1967	252	1037	243
1968	435	1485	293
1969	293	1903	154
1970	167	759	220
1971	135	722	187
1972	58	339	171
1973	57	277	206
1974	74	638	116
1975	37	250	148
1976	182	1338	136
1977	83	546	152
1978	79	506	156
1979	202	842	240
1980	238	881	270
1981	114	573	199
1982	189	738	256
1983	124	623	199
1984	142	724	196
1985	56	424	132
1986	23	295	78
1987	80	442	181
1988	128	780	164

[a] Effort = (Landings)(1000)/CPUE.

[b] CPUE -- Area 5A, April-September. Standardized by loglinear model (See Section 4.0.1.).

Table 4.5. Standardized Canada-U.S. landing statistics for rock sole from Area 5B, January-December 1956-88.

Year	Landings (t)	Effort (h)[a]	CPUE (kg/h)[b]
1956	307	1181	260
1957	206	924	223
1958	379	1779	213
1959	344	1564	220
1960	503	2286	220
1961	416	2273	183
1962	531	2350	226
1963	517	2427	213
1964	482	2087	231
1965	568	2309	246
1966	772	2849	271
1967	741	2861	259
1968	392	1912	205
1969	652	3432	190
1970	245	1201	204
1971	368	1761	209
1972	382	1769	216
1973	324	1645	197
1974	371	1649	225
1975	408	2000	204
1976	368	1947	189
1977	188	1229	153
1978	217	1033	210
1979	208	1182	176
1980	410	1653	248
1981	220	1058	208
1982	155	928	167
1983	206	990	208
1984	87	537	162
1985	170	960	177
1986	135	672	201
1987	205	840	244
1988	272	971	280

[a] Effort = (Landings)(1000)/CPUE.

[b] CPUE -- Area 5B, April-September. Standardized by log-linear model (See Section 4.0.1.).

Table 4.6. Standardized Canada-U.S. landing statistics for rock sole from Area 5C, January-December 1956-88.

Year	Landings (t)	Effort (h)[a]	CPUE (kg/h)[b]
1956	397	954	416
1957	726	2782	261
1958	368	971	379
1959	249	737	338
1960	471	1273	370
1961	110	414	266
1962	322	763	422
1963	155	486	319
1964	244	626	390
1965	539	1761	306
1966	961	2802	343
1967	948	1931	491
1968	811	2351	345
1969	1053	4212	250
1970	694	3385	205
1971	376	1938	194
1972	134	521	257
1973	186	612	304
1974	288	917	314
1975	383	1413	271
1976	277	917	302
1977	272	996	273
1978	356	1582	225
1979	647	2003	323
1980	482	1833	263
1981	126	545	231
1982	70	389	180
1983	60	251	239
1984	64	178	359
1985	28	110	254
1986	86	601	143
1987	209	590	354
1988	189	649	291

[a] Effort = (Landings)(1000)/CPUE.

[b] CPUE -- Area 5C, April-September. Standardized by log-linear model (See Section 4.0.1.).

Table 4.7. Standardized Canada-U.S. landing statistics for rock sole from Area 5D, January-December 1956-88.

Year	Landings (t)	Effort (h)[a]	CPUE (kg/h)[b]
1956	763	1346	567
1957	425	633	671
1958	888	570	1557
1959	167	137	1221
1960	656	428	1534
1961	634	418	1518
1962	507	371	1366
1963	726	567	1280
1964	499	519	961
1965	340	399	852
1966	1583	1560	1015
1967	1214	597	2032
1968	1555	2076	749
1969	1356	1323	1025
1970	709	1003	707
1971	1127	1737	649
1972	381	686	555
1973	321	439	731
1974	334	301	1110
1975	821	1853	962
1976	1161	1725	673
1977	574	1134	506
1978	518	731	709
1979	666	1095	608
1980	495	762	650
1981	458	896	511
1982	221	438	504
1983	187	368	508
1984	124	311	399
1985	84	303	277
1986	133	270	493
1987	327	321	1020
1988	1213	2538	478

[a] Effort = (Landings)(1000)/CPUE

[b] CPUE -- Two Peaks-Butterworth, April-September. Standardized by log-linear model (See Section 4.0.1.).

Table 4.8. Standardized Canada-U.S. landing statistics for English sole, Hecate Strait, January-December 1956-88.

Year	Landings (t)	Effort (h)[a]	CPUE (kg/h)[b]
1956	956	1330	719
1957	552	1693	326
1958	693	2398	289
1959	940	2575	365
1960	1147	1600	717
1961	871	1688	516
1962	459	1297	354
1963	408	3429	119
1964	435	2390	182
1965	414	3696	112
1966	362	5656	64
1967	534	2171	246
1968	671	3338	201
1969	819	2904	282
1970	1002	2616	383
1971	488	2742	178
1972	371	2304	161
1973	667	2527	264
1974	500	2525	198
1975	938	3474	270
1976	1133	8093	140
1977	1179	9211	128
1978	559	5324	105
1979	864	10047	86
1980	995	8805	113
1981	1327	8905	149
1982	428	3690	116
1983	430	3071	140
1984	658	3656	180
1985	585	2683	218
1986	335	2913	115
1987	630	4773	132
1988	688	2567	268

[a] Effort = (landings)(1000)/CPUE.

[b] CPUE = Two Peaks-Butterworth, April-September, option-2 method (Westrheim 1983). Standardized using the method of Westrheim and Foucher (1985a).

Table 4.9. Annual estimates of numbers at age[a] from virtual population analysis for Hecate Strait English sole, 1955-79.

	Age									
Year	3	4	5	6	7	8	9	10	11	12
1955	2769	2934	1665	922	633	297	138	52	91	48
1956	2454	2192	2029	974	521	368	128	47	13	63
1957	2335	1957	1568	1090	503	275	217	73	27	0
1958	2378	1862	1421	1133	651	290	171	152	39	11
1959	2449	1896	1390	906	715	324	143	90	90	21
1960	1950	1953	1299	711	416	380	140	52	44	54
1961	1339	1531	1224	584	229	118	67	35	13	20
1962	1816	1068	989	413	195	62	34	18	11	0
1963	2207	1448	734	522	190	74	23	17	5	6
1964	2786	1759	1073	415	221	85	30	11	8	4
1965	4444	2221	1213	609	216	119	42	20	5	5
1966	1908	3544	1695	757	321	82	53	15	5	2
1967	1064	1522	2764	1171	443	173	29	28	5	4
1968	871	848	1170	1853	659	246	88	2	14	0
1969	1381	689	657	785	1055	328	112	40	0	10
1970	1811	1077	485	418	437	487	131	48	17	0
1971	2194	1402	655	248	225	173	185	38	14	10
1972	2384	1737	903	402	156	135	90	90	8	4
1973	2954	1833	1242	586	262	90	76	38	57	0
1974	2579*	2222	1287	778	372	167	39	30	15	36
1975	1859*	2011*	1613	883	520	225	101	9	19	6
1976	1632*	1461*	1370*	944	456	239	90	29	0	6
1977	1805*	1292*	1031*	690*	428	152	84	12	11	0
1978	2580*	1348*	777*	474*	306*	189	53	27	4	0
1979	7238*	2042*	1002*	501*	307*	192*	110	14	14	3

[a] Numbers marked with an asterisk are considered unreliable because the cumulative fishing mortality for these cohorts is less than 2.0 (Pope 1972).

Table 4.10. Annual estimates of fishing mortality rates (F) for Hecate Strait English sole, 1955-79.

	Age									
Year	3	4	5	6	7	8	9	10	11	12
1955	0.01	0.15	0.32	0.35	0.32	0.62	0.85	1.21	0.14	0.18
1956	0.01	0.12	0.40	0.44	0.42	0.31	0.35	0.33	5.29	0.19
1957	0.01	0.10	0.11	0.30	0.33	0.26	0.13	0.41	0.66	0.25
1958	0.01	0.07	0.23	0.24	0.48	0.49	0.42	0.31	0.37	0.35
1959	0.01	0.16	0.45	0.56	0.41	0.62	0.79	0.49	0.30	0.37
1960	0.02	0.25	0.58	0.91	1.04	1.52	1.16	1.19	0.55	0.23
1961	0.01	0.22	0.87	0.88	1.09	1.03	1.10	0.90	5.05	0.24
1962	0.01	0.16	0.42	0.56	0.75	0.77	0.44	1.11	0.49	0.19
1963	0.01	0.08	0.35	0.64	0.59	0.68	0.49	0.59	0.01	0.50
1964	0.01	0.15	0.35	0.43	0.40	0.48	0.21	0.67	0.16	0.35
1965	0.01	0.05	0.25	0.42	0.75	0.59	0.79	1.11	0.65	0.54
1966	0.01	0.03	0.15	0.32	0.40	0.84	0.43	0.85	0.01	0.82
1967	0.01	0.04	0.18	0.35	0.37	0.45	2.35	0.44	4.99	0.31
1968	0.01	0.04	0.18	0.34	0.48	0.57	0.57	3.46	0.17	0.48
1969	0.03	0.13	0.23	0.37	0.55	0.70	0.63	0.63	0.23	0.42
1970	0.04	0.28	0.45	0.40	0.71	0.75	1.02	1.03	0.30	0.38
1971	0.01	0.22	0.27	0.24	0.29	0.43	0.50	1.29	1.03	0.40
1972	0.04	0.12	0.21	0.21	0.33	0.35	0.64	0.24	5.23	0.33
1973	0.06	0.13	0.25	0.24	0.23	0.62	0.71	0.73	0.24	0.37
1974	0.03	0.10	0.16	0.18	0.28	0.28	1.20	0.25	0.75	0.37
1975	0.02	0.16	0.32	0.44	0.56	0.70	1.04	5.55	0.87	0.50
1976	0.01	0.13	0.47	0.57	0.88	0.83	1.79	0.70	0.47	1.17
1977	0.07	0.29	0.56	0.59	0.60	0.84	0.93	1.00	6.11	1.34
1978	0.01	0.08	0.22	0.21	0.25	0.32	1.14	0.40	0.01	0.77
1979	0.02	0.13	0.33	0.42	0.52	0.63	0.82	1.04	1.42	1.46
Mean	0.02	0.13	0.33	0.42	0.52	0.63	0.82	1.04	1.42	0.50
C.V.	0.95	0.53	0.51	0.45	0.45	0.43	0.59	1.09	1.43	0.70

Table 4.11. Standardized Canada-U.S. landing statistics for Dover sole, Areas 5C, D, E, 1970-87.

Year	Landings (t)	Effort (h)[a]	CPUE (kg/h)[b]
1970	965	872	1107
1971	903	862	1048
1972	922	899	1026
1973	768	600	1280
1974	767	604	1270
1975	882	904	976
1976	1022	1433	713
1977	577	1085	532
1978	483	1032	468
1979	697	1394	500
1980	807	1204	670
1981	840	1409	596
1982	512	998	513
1983	693	949	730
1984	953	1209	788
1985	830	1172	708
1986	1040	1294	804
1987	503	490	1026
1988	649	931	697

[a] Effort (h) = landings (1000)/CPUE.

[b] CPUE -- Dundas, June-September.
Standardized by log-linear model (See Section 4.0.1.).

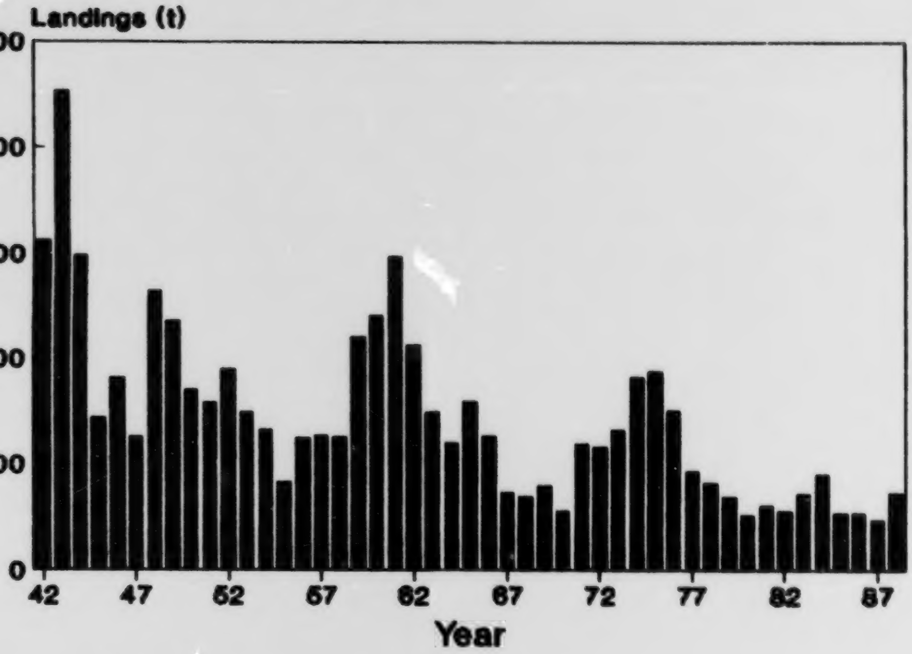


Fig. 4.1. Canada-U.S. landings of petrale sole from the "southern stock" 1942-88.

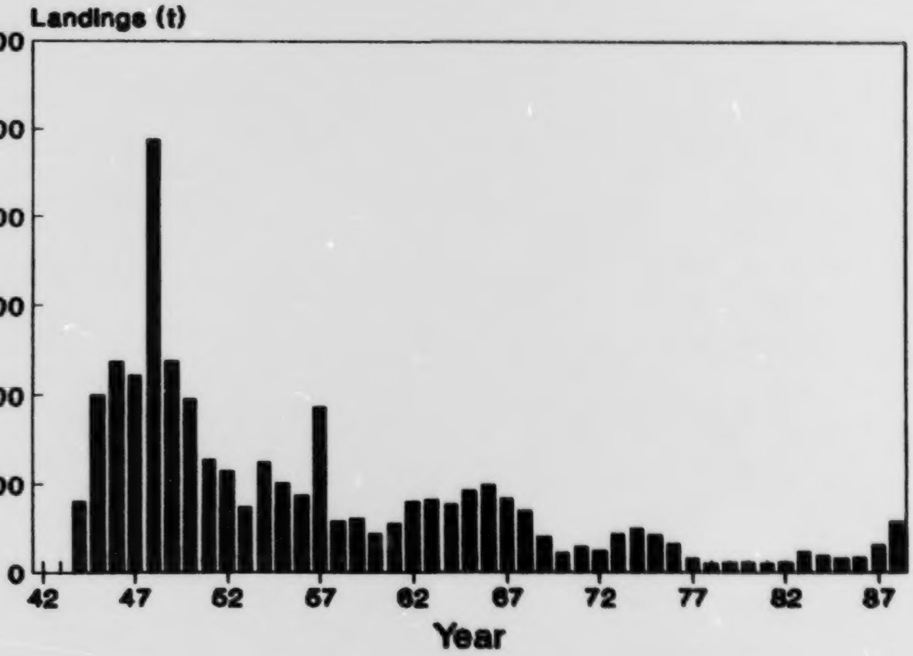


Fig. 4.2. Canada-U.S. landings of petrale sole from the "northern stock" 1942-88.

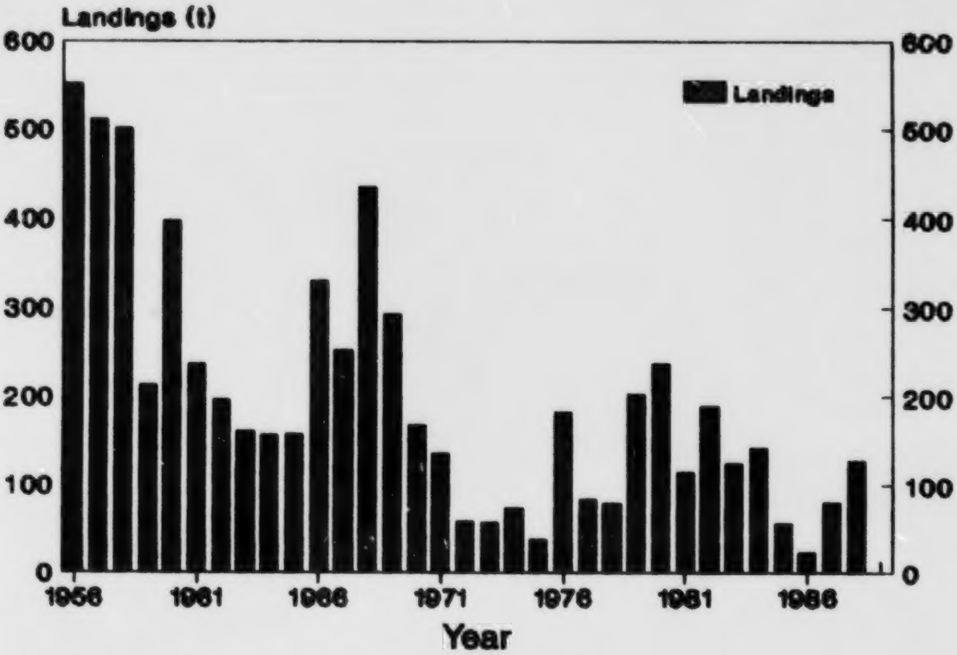


Fig. 4.3. Canada-U.S. landings for rock sole from Area 5A, 1956-88.

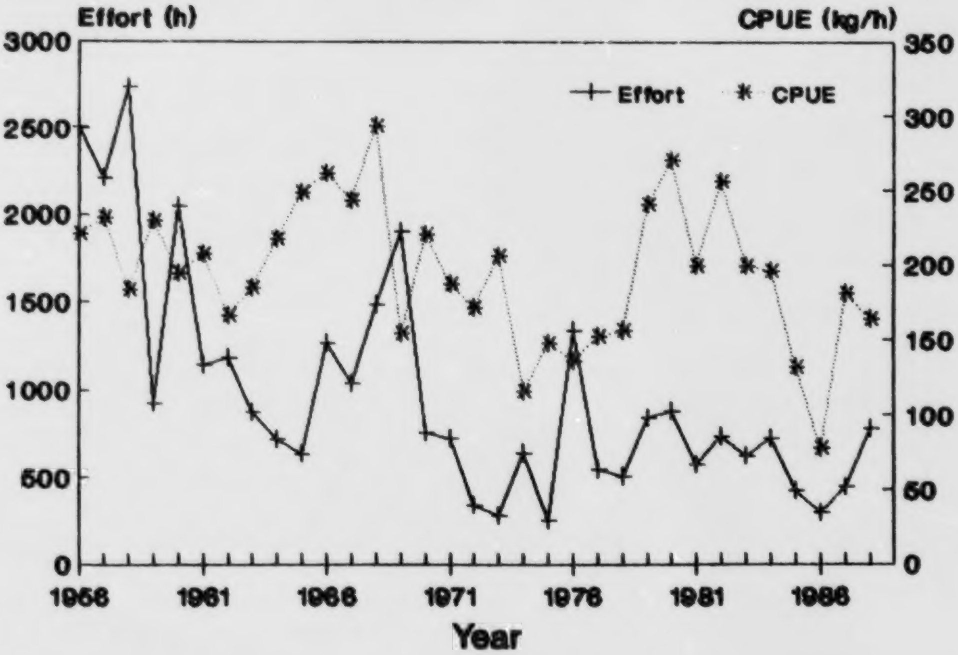


Fig. 4.4. Standardized effort and CPUE for rock sole from Area 5A, 1956-88.

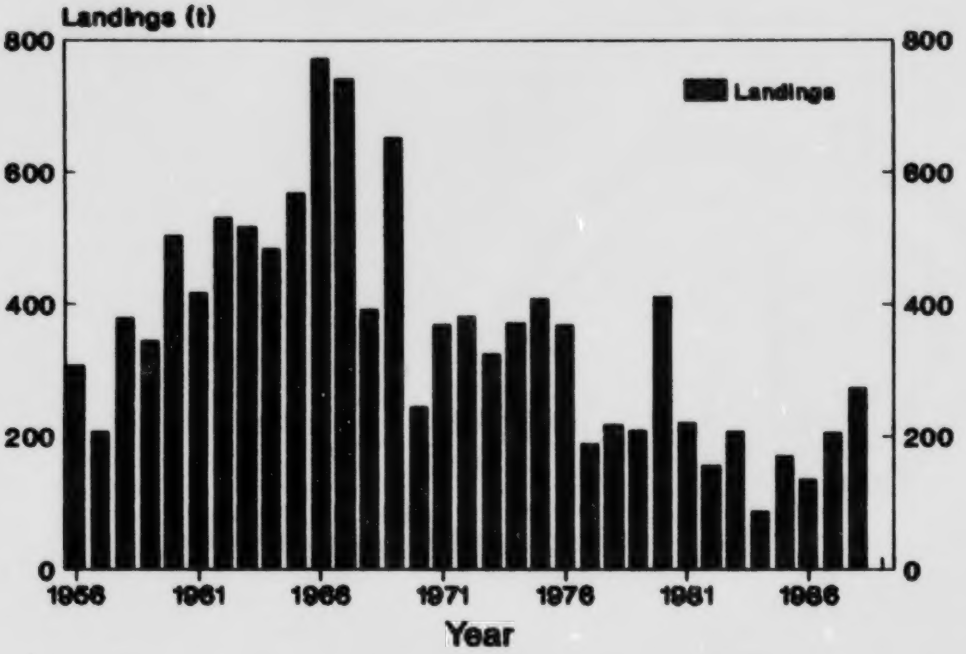


Fig. 4.5. Canada-U.S. landings for rock sole from Area 5B, 1956-88.

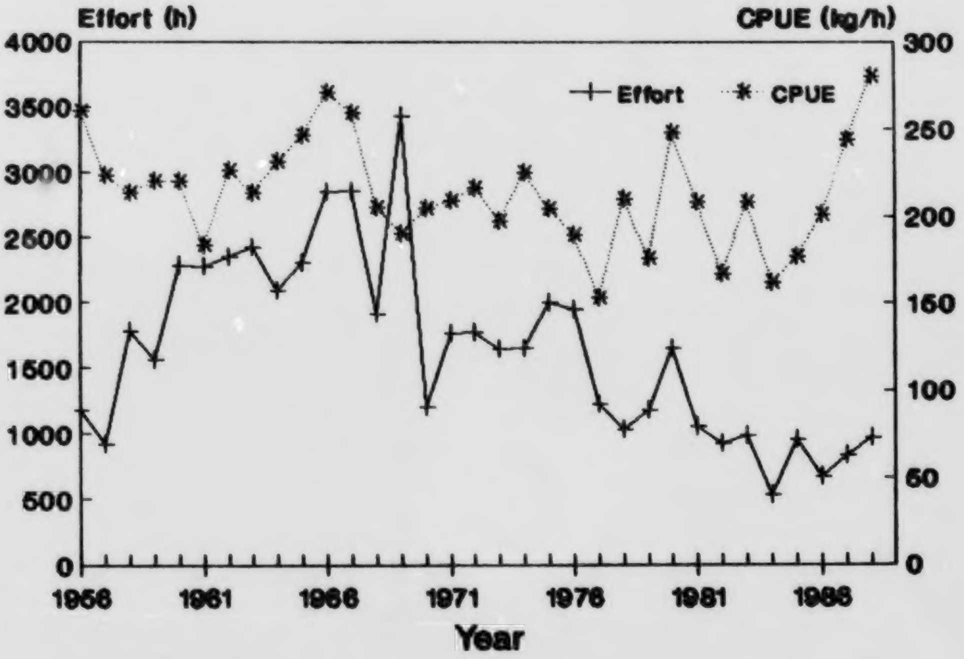


Fig. 4.6. Standardized effort and CPUE for rock sole from Area 5B, 1956-88.

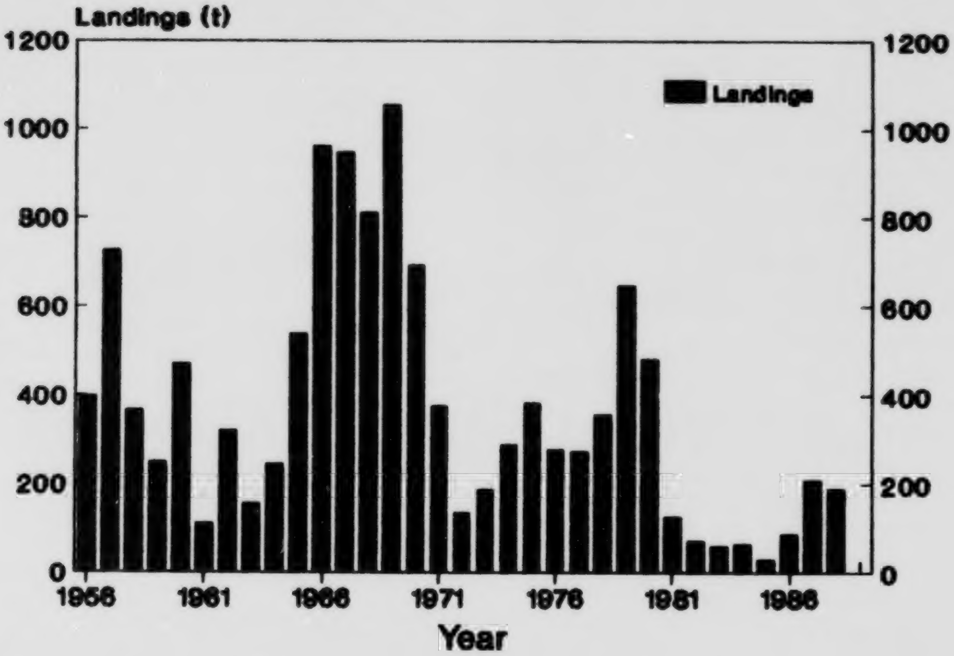


Fig. 4.7. Canada-U.S. landings for rock sole from Area 5C, 1956-88.

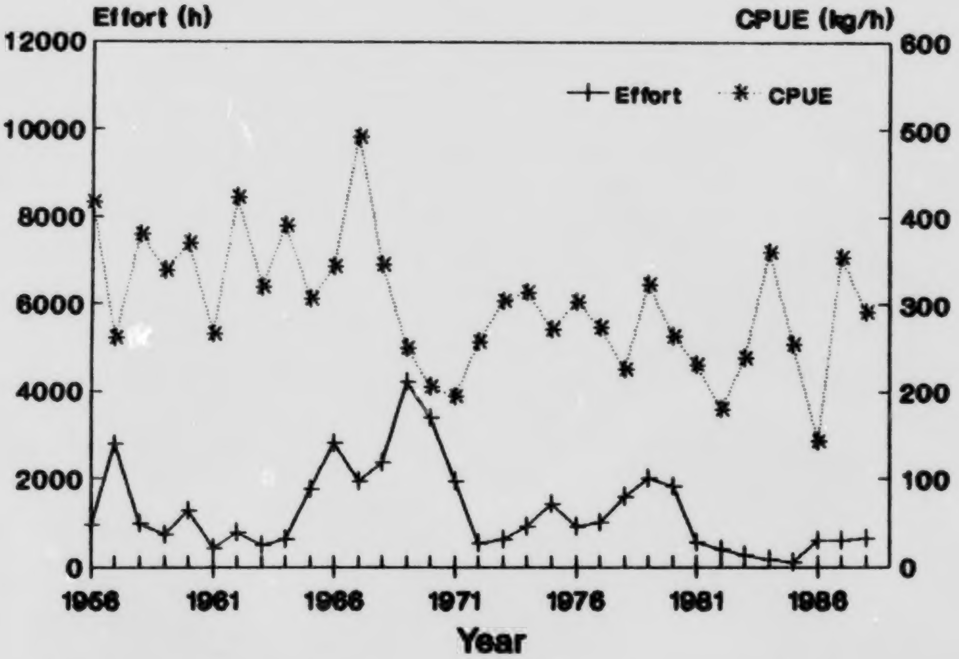


Fig. 4.8. Standardized effort and CPUE for rock sole from Area 5C, 1956-88.

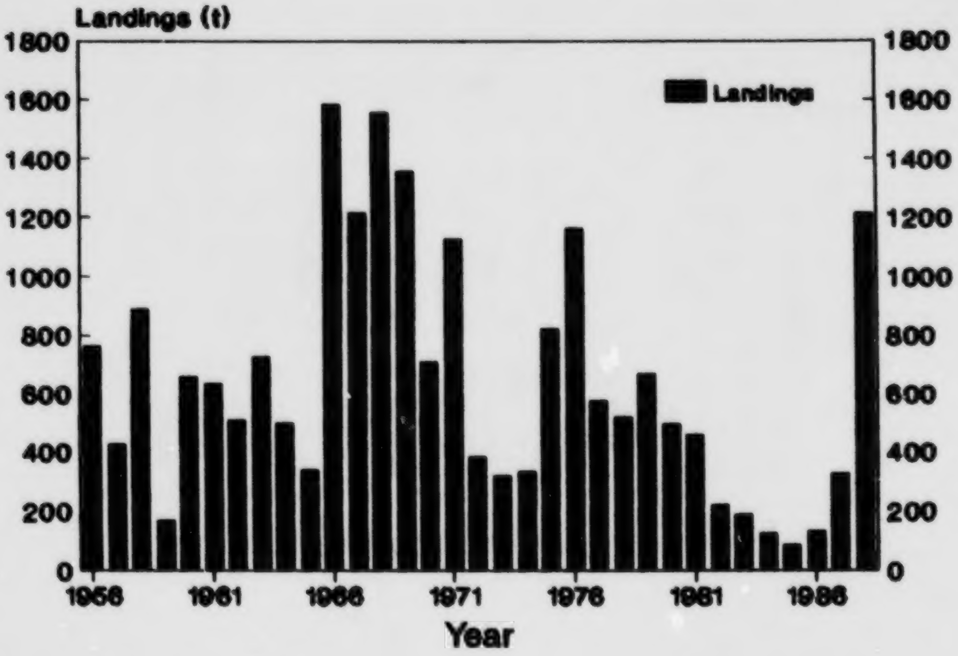


Fig. 4.9. Canada-U.S. landings for rock sole from Area 5D, 1956-88.

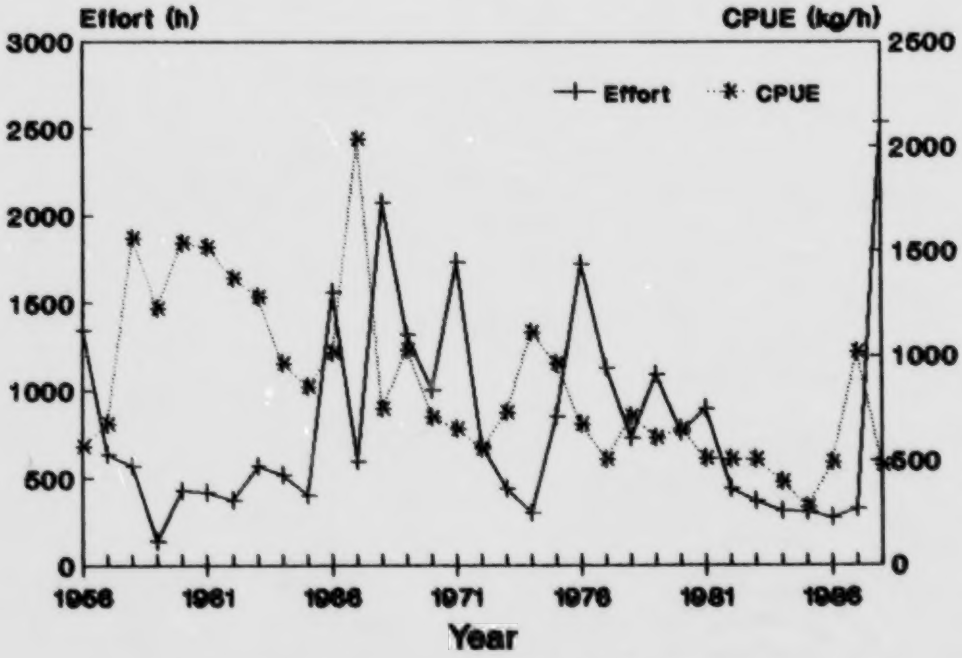


Fig. 4.10. Standardized effort and CPUE for rock sole from Area 5D, 1956-88.

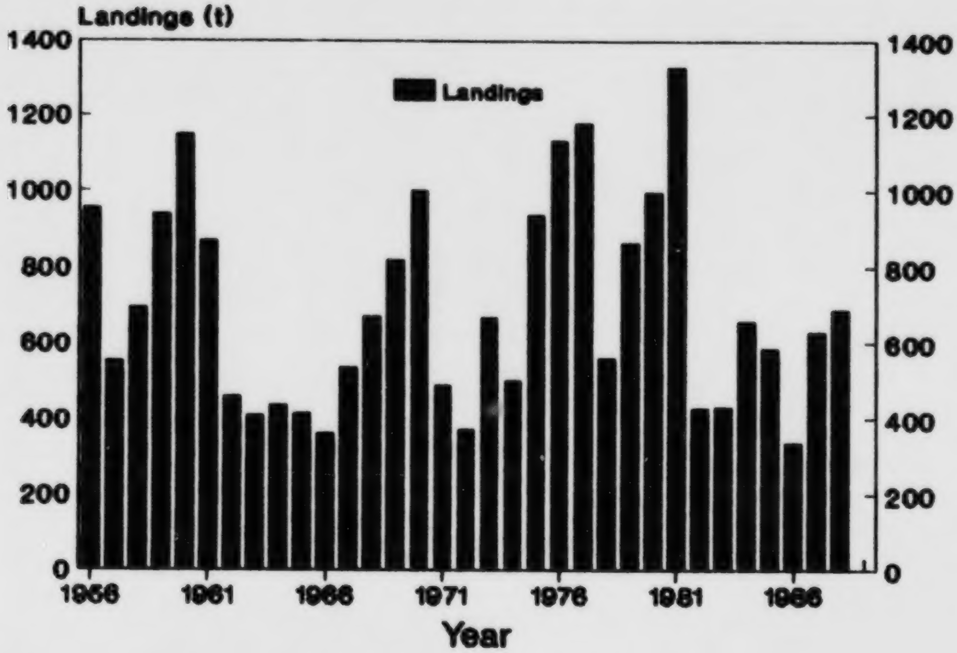


Fig. 4.11. Canada-U.S. landings for English sole from Hecate Strait, 1956-88.

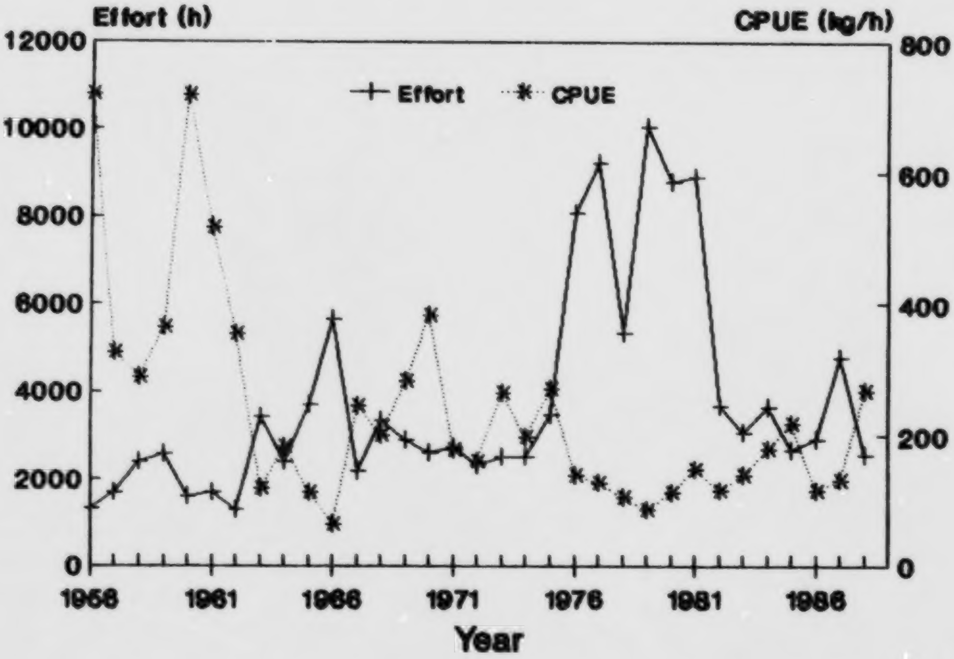


Fig. 4.12. Standardized effort and CPUE for English sole from Hecate Strait, 1956-88.

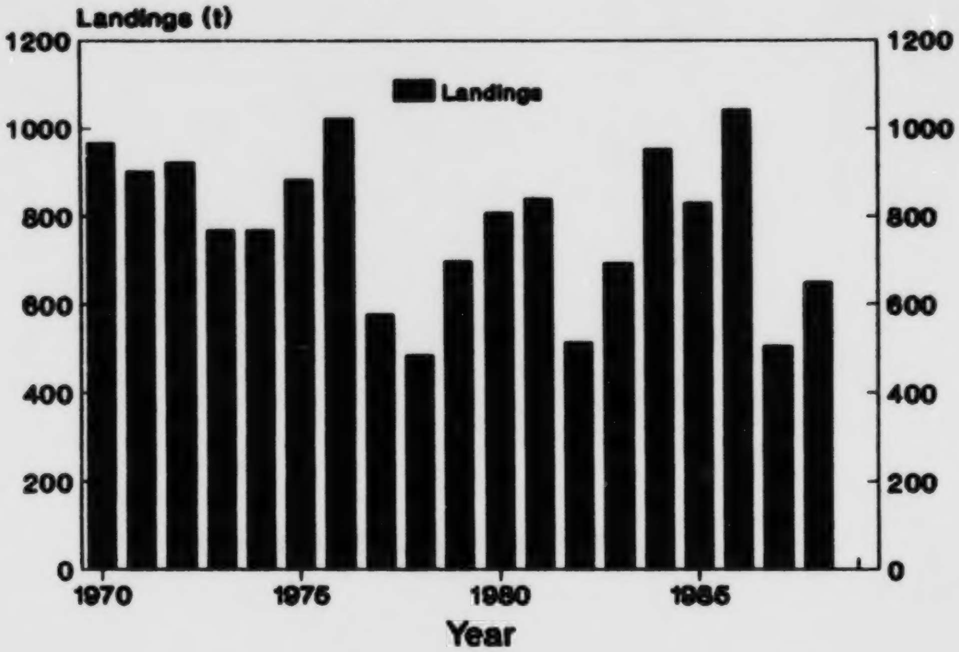


Fig. 4.13. Canada-U.S. landings for Dover sole from Areas 5C, D, E, 1970-88.

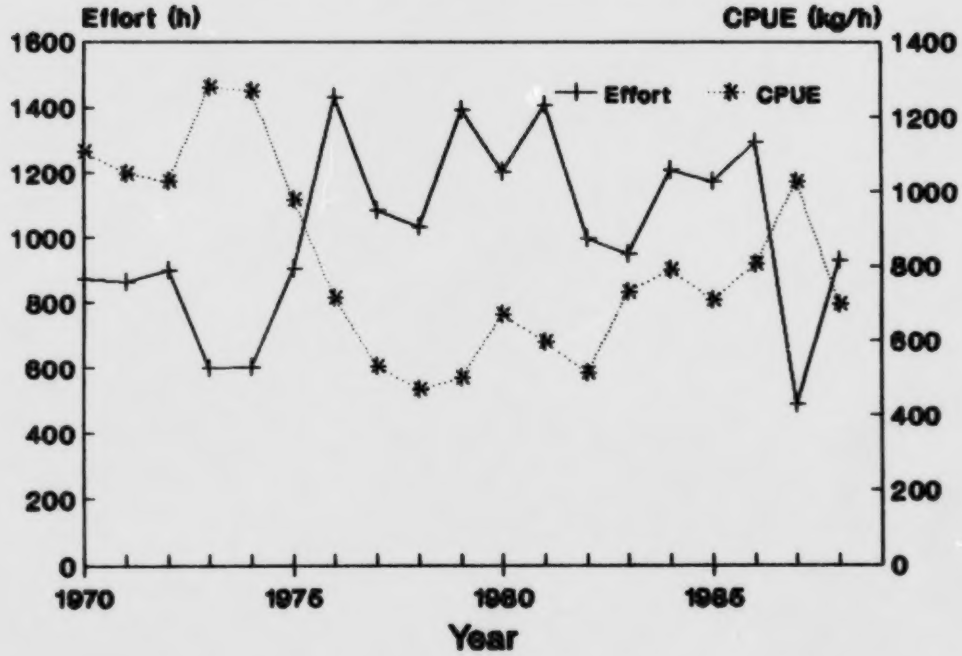


Fig. 4.14. Standardized effort and CPUE for Dover sole from Areas 5C, D, E, 1970-88.

5.0 SABLEFISH

by M. W. Saunders and G. A. McFarlane

5.1 Coastwide

5.1.2. Landing Statistics

In 1988 a total of 5217 t of sablefish were caught coastwide by trap, trawl, and longline. Nominal catch from the west coast of the Queen Charlotte Islands, Queen Charlotte Sound, and Hecate Strait decreased slightly from 2635.1 t in 1987 to 2438.9 t in 1988, with the majority (82.7%) caught by trap (Table 5.1).

Catch from the west coast of Vancouver Island increased to 2778.1 t in 1988 from 2554.2 t in 1987. The largest proportion of fish were trap-caught (46.9%) (Table 5.2). The longline component (36.7%) continues to increase, with most previously inactive longline licences entering the fishery off the southwest coast of Vancouver Island during the August and September openings.

The trap and longline components appear to have similar selectivity patterns. Histograms of the proportion of the catch by weight categories for the two gear types, in 1987 and 1988, are presented in Figure 5.1. Although similar, the longline fishery catches a slightly higher percentage of large fish than the trap fishery.

Trawl catch from the west coast of Vancouver Island increased to 454.0 t in 1988 from 271.5 t in 1987. Similarly, trawl landings from all other areas combined increased to 176.7 t in 1988 from 167.9 t in 1987 (Tables 5.1 and 5.2).

5.1.3 General Biological Information

The age frequency for 1987 is presented in Figure 5.2. The fishery continues to be dominated by ages 5 to 10.

5.1.4 Condition of the Stock

STANDARDIZATION OF EFFORT

During 1988 and 1989 an increase in nominal trap CPUE has been noted coastwide (Table 5.3, Figure 5.3). Coincidentally, there has been a management change during these same two years with individuals from the 48-licence fleet able to choose from monthly openings from February to September rather than the previous one or two openings per year. This strategy has eliminated timing and gear conflicts.

To determine whether the increase in CPUE is due to changes in execution of the fishery, it was necessary to standardize effort. A number of factors other than fish abundance could influence trap CPUE, including trap type, bait, area, soak time, depth, season, and skipper.

Logbook records of catch and effort for the sablefish trap fishery from 1979 to 1989 maintained as part of the groundfish catch and effort data base at the Pacific Biological Station, were used. The 1989 numbers are preliminary to July 28, 1989. The basic unit of CPUE (kg/trap) does not always represent the catch per unit effort for an individual skate of gear but rather the cumulative catch and traps set during a trip by a vessel in a particular locality. Localities are a further breakdown of minor statistical areas (Figure 1.2) which refer to specific fishing grounds. Only conical (Korean) style traps were used in the analysis. Major statistical areas other than 3, 4, 5, 6, and 9 were eliminated.

Depth and soak time are two continuous variables that may have an effect but are not adequately resolved in the data base. As discussed earlier the basic unit of CPUE often represents more than one skate of gear therefore the depth and soak times are simply an unweighted mean of the skates combined. In order to minimize the effect of these variables the infrequently occurring large and small values were eliminated using the following criteria. The majority of soak times fell below 30 hours so records with soak times greater than 30 hours were not used. Only records with average depths between 150 and 650 metres were used. The distribution of effort by depth category has been consistent since 1985 with most effort set between 300-400 metres (Figure 5.4), hence it is unlikely that changes in the depth of fishing could have influenced CPUE in recent years.

The mean CPUE values at each level of discrete variable including skipper, area, month and bait, were examined using a General Linear Model (SAS 1988). Scheffe and Gabriel multiple range procedures were applied in cases where variables were found to affect CPUE significantly to determine where differences occurred. Levels of each variable that were not significantly different in their effect on CPUE were combined to produce simpler and more meaningful groupings.

The type of bait used in the fishery has changed considerably over the years. The proportion of traps using a particular bait by year is presented in Figure 5.5. During 1979 and 1980 herring was used. This changed rather abruptly in 1981 when squid came into use. Since that time squid has been used increasingly in combination with herring and most recently in combination with hake. Although the increase in CPUE coincides with the use of hake as bait, the amount of variation in mean CPUE explained by the change in bait is very small.

CPUE was examined by month and found to be significantly higher in winter months (November-February) than in summer months. Consequently records were grouped by winter and summer. The seasonal difference may be a result of changing behaviour related to spawning.

Catch rates were examined by minor statistical area. Areas north of and including minor area 8 were found to be significantly different from areas south. Again, records were split into two groups north and south.

While a total of 41 skippers have participated in the trap fishery, many have contributed a limited number of landings. Skippers with less than an arbitrarily chosen 15 records were eliminated from the data base, leaving 18 skippers.

CPUE was standardized using a multiplicative General Linear Model (SAS 1988). The model incorporating skipper, area, season, and year explained 38.5% of the variation in mean CPUE. The resulting trend in CPUE is presented in Figure 5.3. The standardized series continues to indicate an increase of CPUE in 1988 and 1989. Attributing the change to an increase in abundance must be viewed with cautious optimism. The change could still be the result of some aspect of the fishery over the last two years not yet investigated. For example the decrease in numbers of vessels on the grounds at any given opening could result in more fishermen having access to preferred grounds. As with the halibut fishery, shorter openings may lead to higher CPUE. Longer openings result in localized depletions which decrease the overall CPUE.

Another possibility is that the change may be due to a change in availability. Figure 5.6 presents CPUE by individual fish dressed weight (lb) category. CPUE in this case was calculated by dividing catch by pound category from saleslip information maintained by DFO's offshore division, by total effort. Total effort was calculated by dividing the total catch by CPUE from logbook records maintained at PBS. During 1987 and 1988 all of the weight categories increase simultaneously, an indication that a change in availability may have taken place. It is difficult to see how an increase in recruitment could be consistent with this finding. Increased recruitment should have led to an increase in the small fish categories only.

CATCH-AT-AGE ANALYSIS

The approach taken in this assessment is similar to that reported in the 1988 assessment (Saunders et al. 1988). A forward simulation model (Tyler 1982) was used to make projections of sablefish biomass and yield. The numbers-at-age used as the starting vector for the forward simulation were calculated using virtual population analysis (VPA) (Gulland 1983).

The VPA was run using nine years of age composition data from 1979 to 1987. The catch-at-age data used in the VPA are presented in Table 5.4. The catch-at-age indicates that the fishery is becoming increasingly dependant on younger fish. The cause of this age-frequency truncation could be the result of a number of factors. First of all, the increasing price for small fish (< 60 cm) since 1984 and the shorter duration of the fishery has led to more smaller fish being landed.

Secondly, the truncation could be the result of fishing down the older ages. If true, then the rapid loss of the older ages and the dependence of the fishery on 10-15 year-classes is cause for concern for a species with documented low periods of recruitment.

To reduce the error in estimating recruitment in the forward simulations, numbers at age 5 from the VPA were used rather than numbers at age 4 which had been used in previous assessments.

Two natural mortality rates (0.1 and 0.15) were used due to the sensitivity of the analysis to M. A Terminal F value of 0.1 was used in the VPA. See Saunders et al. (1988) for a discussion of the sensitivity of the analysis to varying rates of M and Terminal F. The annual estimates of numbers-at-age, fishing mortality rates (F), total mortality rates (Z), and exploitation rates from the VPA (using M=0.1 (McFarlane et al. 1985)) are presented in Tables 5.5, 5.6, 5.7, and 5.8, respectively, with totals presented in Table 5.9. It must be noted that because the cumulative F values for all cohorts in the VPA are less than two, the numbers-at-age, cannot be considered accurate (Pope 1972).

The numbers at age 5 suggest that we are entering a period of moderate to high recruitment. The absolute size of these incoming age-classes is difficult to determine given the inaccuracy of the VPA estimates in the most recent years.

In all runs of the forward simulation model, the numbers-at-age in 1979 from the VPA were used. The numbers-at-age in 1989 were estimated by running the simulation from 1979 and incorporating catches from 1979 to 1988 with the catch in 1989 assumed to be equal to 5000 t.

The numbers recruiting at age 5 were taken from the VPA. The numbers at age 5 in 1979 (1974 year-class) was used as a low level of recruitment. The number at age 5 for the 1979 year-class was used for the moderate to strong recruitment level and the median of the high and low levels was used as a median level.

If the goal is to manage to an F 0.1 level, a projection to 1989 can be utilized and the F 0.1 level of F applied to the stock. The values for $F_{0.1}$ and $F_{0.05}$ are F=0.205 and F=0.1025 respectively. Beyond 1988, F levels of 0.205 and 0.1025 under low, average and high recruitment assumptions result in the following yields, in tonnes for 1990:

M	F	Recruitment		
		Low	Med	Hi
0.1	0.205	2699	3819	4923
0.1	0.1025	1405	1981	3813
0.15	0.205	3565	4990	6409
0.15	0.1025	1856	2591	3323

These correspond to the F0.1 and F0.05 levels from yield per recruit analysis (McFarlane et al. 1985). While F0.1 is assumed to be conservative for most species, it is not known if it is conservative for a long-lived species with periods of low recruitment. It is likely that the acceptable catch level is somewhere between the two. The projections indicate that biomass is in the order of 30 thousand t and that with average and low recruitment the recruited biomass will continue to decline slightly at F of 0.205 and increase slightly at an F of 0.1025 (Figure 5.7).

Appropriate levels of recruitment introduce the most uncertainty into this assessment. Work is currently underway on determining the factors that influence year-class strength. As well, an index of year-class strength based on the abundance of 0+ fish has been under development since 1984. In 1988, the first year-class surveyed began to recruit to the fishery as age 4-5 fish and over the next five years the ability of the survey to predict year-class strength will be demonstrated. In the past, strong year-classes have been approximately ten years apart. Although there is indication that moderate to strong year-classes have occurred since 1977 it is possible that persistently poor recruitment could occur again as it did in the mid-1970s. Should this happen, available yields would decline.

5.1.5 Yield Options

Risk in the yield options below is a function of the uncertainty regarding recruitment. There exists a strong possibility that the high-risk level may interfere with the future yield.

Variable Yield

Given a commitment to an F 0.1 approach, the following levels are appropriate. Again, risk is associated with the uncertainty regarding appropriate recruitment levels from 1985 to the present. The high risk level is the mid-point between the F levels assuming high recruitment and high natural mortality. The low risk level is the mid-point between the F levels assuming average recruitment and low natural mortality. The sustainable level is the mid-point between the high and low risk levels.

Sustainable - low risk -	2900 t
Sustainable -	4000 t
Sustainable - high risk -	5000 t

Constant Effort

Managers may want to consider implementing a constant effort policy which would simplify management. Barring any major innovations the fleet should be approaching a level of maximum efficiency. If true, the number of days could be fixed with yield decreasing or increasing to an appropriate level given changes in abundance. An analysis of fleet efficiency should be undertaken in the event that management would like to consider this option.

Table 5.1. Canadian sablefish nominal catch, by gear, from Queen Charlotte Sound, Hecate Strait, and the west coast of the Queen Charlotte Islands, 1973-1988 (Major Areas 5A, 5B, 5C, 5D and 5E) (round wt, metric tonnes)[a], excluding dumped and discarded fish.

	Gear type								
	Longline		Trawl		Trap		Other[b]		
Year	Wt	%[c]	Wt	%	Wt	%	Wt	%	Total
1973	116.6	21.6	31.7	5.9	392.4	72.6	-	-	540.7
1974	39.0	16.1	38.1	15.7	165.6	68.2	-	-	242.7
1975	149.9	22.7	82.0	12.4	427.9	64.9	-	-	659.8
1976	47.7	10.4	154.2	33.7	255.8	55.9	-	-	457.7
1977	49.8	16.9	98.3	33.4	145.7	49.4	.9	.3	294.7
1978	39.0	8.2	40.4	8.5	395.1	83.0	1.4	.3	475.9
1979	158.7	11.7	132.7	9.8	1067.6	78.5	-	-	1359.0
1980	179.7	9.5	228.6	12.0	1488.3	78.5	-	-	1896.6
1981	238.1	8.7	90.4	3.3	2412.6	88.0	-	-	2741.1
1982	181.8	6.3	88.3	3.1	2595.2	90.1	16.5[d]	.5	2865.3
1983	108.4	3.5	116.5	3.7	2901.2	92.3	15.6[e]	.5	3141.7
1984	153.9	6.7	64.8	2.8	2082.2	90.5	-	-	2300.9
1985	298.9	13.0	135.1	5.9	1864.1	81.1	-	-	2298.1

Table 5.1. (cont'd)

	Gear type								
	Longline		Trawl		Trap		Other[b]		
Year	Wt	%[c]	Wt	%	Wt	%	Wt	%	Total
1986	159.3	6.2	184.8	7.2	2215.9	86.6	-	-	2560.0
1987	164.4	6.2	167.9	6.4	2302.5	87.4	.3	-	2635.1
1988	243.4	10.0	176.7	7.2	2016.7	82.7	2.1	.1	2438.9

[a] Fisheries Research Board of Canada Catch and Effort statistics of the Canadian Groundfish Fishery of the Pacific coast, 1973-1981. Statistics from 1982 to 1988 from Department of Fisheries and Oceans, Pacific Biological Station groundfish data base.

[b] Includes troll and handline.

[c] Percent of total landed by all gears within a year.

[d] Incidental to halibut longline.

[e] Includes troll, handline, sunken gillnet and catch incidental to halibut longline fishery.

Table 5.2. Canadian sablefish landing, by gear, from west coast Vancouver Island (Major Areas 3C and 3D), 1973-1988 (round wt, metric tonnes)[a], excluding dumped and discarded fish.

	Gear type								
	Longline		Trawl		Trap		Other[b]		
Year	Wt	%[c]	Wt	%	Wt	%	Wt	%	Total
1973	3.2	0.8	50.9	12.5	353.4	86.7	Tr	Tr	407.5
1974	2.3	0.9	83.7	33.6	161.5	64.8	1.8	0.7	249.3
1975	2.3	0.9	200.3	81.8	41.5	16.9	0.9	0.4	245.0
1976	41.7	13.3	224.8	71.5	47.6	15.1	0.1	0.0	314.2
1977	27.3	3.5	688.4	87.1	68.9	8.7	5.9	0.7	790.5
1978	18.2	5.1	89.9	25.4	239.5	67.7	6.4	1.8	354.0
1979	118.3	17.5	143.4	21.2	409.8	60.5	6.0	0.9	677.5
1980	69.1	3.6	106.8	5.6	1722.5	90.6	3.0	0.2	1901.4
1981	94.8	8.6	140.2	12.8	862.4	78.6	–	–	1097.4
1982	161.9	13.2	153.2	12.5	913.3	74.2	1.9[d]	0.2	1230.3
1983	343.1	27.1	146.7	11.6	777.0	61.3	–	–	1266.8
1984	211.2	13.9	120.0	7.9	1188.9	78.2	–	–	1520.1
1985	159.4	8.4	93.9	5.0	1637.2	86.6	–	–	1890.5
1986	459.2	24.8	365.4	19.7	1026.6	55.5	–	–	1851.2
1987	770.4	30.2	271.5	10.6	1512.3	59.2	–	–	2554.2
1988	1020.0	36.7	454.0	16.3	1303.1	46.9	1.2	0.1	2778.1

[a] Fisheries Research Board of Canada Catch and Effort statistics of the Canadian Groundfish Fishery of the Pacific coast, 1973-1981. Statistics from 1982 to 1988 from Department of Fisheries and Oceans, Pacific Biological Station groundfish data base.

[b] Includes troll and handline.

[c] Percent of total landed by all gears within a year.

[d] Incidental to halibut longline.

Table 5.3. Coastwide sablefish trap nominal and standardized CPUE (kg/trap), for 1978-1988.

Year	Nom.	Stand.
1979	16.5	14.4
1980	14.2	16.8
1981	16.6	16.0
1982	24.3	19.1
1983	16.4	14.8
1984	13.4	11.7
1985	15.7	12.7
1986	14.7	7.9
1987	13.7	11.2
1988	19.8	21.2
1989	22.6	22.6

Table 5.4. Catch-at-age in numbers for sablefish from 1979-1987.

	Year								
Age	1979	1980	1981	1982	1983	1984	1985	1986	1987
5	2019	10720	40098	141704	98401	185136	88306	117901	115277
6	2019	28075	24059	60987	331688	178016	195930	188642	183557
7	2019	34711	33312	36472	87344	286012	289755	166303	196858
8	2019	35732	15422	44245	38697	46284	237323	183678	224347
9	2019	41858	22825	51420	35380	34416	88306	100526	185330
10	18175	42368	30228	41256	54176	24922	22077	28545	92222
11	26252	63297	32078	63976	26535	26109	16557	13652	36357
12	30291	74527	47501	48430	49753	11868	4139	13652	14188
13	38369	82184	36397	54410	35380	23735	4139	19857	10641
14	64621	65339	40715	41854	44225	15428	17937	12411	7981
15	50485	58193	43799	59193	47542	16615	11038	13652	6207
16	60583	71465	36397	31091	27641	9494	4139	14893	5320
17	92893	60234	33929	22720	38697	7121	2760	12411	7094
18	76738	47473	27760	26906	26535	2374	5519	8687	2660
19	74718	45942	28377	19133	29852	14241	2760	7446	11528
20	68660	42879	22208	20329	28746	3560	5519	19857	13301
21	80777	39306	24676	19731	24324	2374	2760	9929	3547
22	78757	30628	22208	9567	21007	1187	1380	8687	6207
23	68660	16845	24059	10164	17690	3560	1380	6205	3547
24	64621	15824	17273	8969	14373	1187	1380	9929	4434
25	32311	15824	9253	10164	4423	1187	1380	9929	6207
26	32311	18377	11104	4783	6634	2374	1380	9929	7094
27	20194	9699	6169	7773	3317	2374	1380	11170	887
28	20194	10720	8636	2392	3317	1187	1380	1241	3547
29	6058	5105	4935	2392	4423	1187	1380	8687	2660
30	12117	10209	5552	2392	1106	1187	1380	6205	6207
31	8078	6636	1851	598	2211	1187	1380	1241	887
32	4039	2552	4935	1196	4423	1187	1380	4964	1773
33	8078	2552	1851	1794	1106	1187	1380	2482	887
34	2019	2042	1851	598	1106	1187	1380	3723	887
35	4039	1531	5552	598	1106	1187	1380	2482	2660

Table 5.5. Annual estimates of sablefish numbers-at-age from Virtual Population Analysis (M=0.1, Terminal F = 0.1).

					Year				
Age	1979	1980	1981	1982	1983	1984	1985	1986	1987
5	408790	416445	825994	2301011	2740794	3068677	2404654	2624286	2773391
6	389366	368498	365657	709477	1944802	2379917	2591525	2087780	2255150
7	284974	350977	306797	308531	586708	1438837	1981424	2157600	1709330
8	420537	254765	284801	245745	245081	449406	1026361	1522823	1784247
9	363881	379094	197326	242692	179756	185228	364421	703729	1205900
10	396582	325367	303243	157316	171092	129547	135040	247051	540851
11	458731	340761	254025	246033	102999	103231	93880	100938	196959
12	467306	390904	248482	199823	161460	68252	68693	69036	77949
13	367526	394315	283481	180159	135443	98853	50265	58012	49736
14	386999	294959	277592	221451	111818	88791	67067	41567	33895
15	330737	288352	205786	212629	161046	59566	65998	43697	25884
16	318243	252478	205246	144434	136096	100875	38082	49164	26599
17	368985	230815	160370	150957	101679	96617	81936	30582	30414
18	319820	245552	151348	113033	115237	55018	80440	71169	15870
19	240042	216994	177880	110454	76739	79076	47443	67866	55984
20	289828	146907	152237	134439	81381	41063	58186	40428	54287
21	240852	197849	92221	117001	102628	46079	33620	47254	17856
22	261992	141870	141143	60019	86926	70052	39560	27802	33271
23	150628	163462	98979	106673	45124	59058	62057	34357	16924
24	150941	71243	132549	66666	86623	24069	49995	54932	25282
25	107403	75876	49704	103482	51985	64602	20672	43886	40424
26	95607	66952	53416	36084	83982	42990	57218	17441	30267
27	135919	56140	43120	37604	28153	69450	36633	50251	6388
28	119285	103758	41776	33140	26502	22369	60320	31801	34745
29	53734	88493	83298	29442	27818	20847	19061	53389	27600
30	50664	42983	75408	70515	24347	21025	17765	15870	39936
31	29301	34383	29329	62782	61247	20921	17916	14691	8464
32	18698	18813	24818	24750	56110	53181	17828	14816	12149
33	82159	13045	14666	17702	21259	46401	47075	14743	8730
34	21850	66676	9406	11537	14358	18116	40743	41311	10960
35	42130	17889	58499	6720	9904	11993	15286	35388	33823

Table 5.6. Annual estimates of sablefish fishing mortality rates (F) from Virtual Population Analysis (M=0.1, Terminal F=0.1).

Age	Year								
	1979	1980	1981	1982	1983	1984	1985	1986	1987
5	0.00	0.03	0.05	0.07	0.04	0.07	0.04	0.05	0.04
6	0.00	0.08	0.07	0.09	0.20	0.08	0.08	0.10	0.09
7	0.01	0.11	0.12	0.13	0.17	0.24	0.16	0.09	0.13
8	0.00	0.16	0.06	0.21	0.18	0.11	0.28	0.13	0.14
9	0.01	0.12	0.13	0.25	0.23	0.22	0.29	0.16	0.18
10	0.05	0.15	0.11	0.32	0.41	0.22	0.19	0.13	0.20
11	0.06	0.22	0.14	0.32	0.31	0.31	0.21	0.16	0.22
12	0.07	0.22	0.22	0.29	0.39	0.21	0.07	0.23	0.21
13	0.12	0.25	0.15	0.38	0.32	0.29	0.09	0.44	0.25
14	0.19	0.26	0.17	0.22	0.53	0.20	0.33	0.37	0.28
15	0.17	0.24	0.25	0.35	0.37	0.35	0.19	0.40	0.29
16	0.22	0.35	0.21	0.25	0.24	0.11	0.12	0.38	0.24
17	0.31	0.32	0.25	0.17	0.51	0.08	0.04	0.56	0.28
18	0.29	0.22	0.21	0.29	0.28	0.05	0.07	0.14	0.19
19	0.39	0.25	0.18	0.21	0.53	0.21	0.06	0.12	0.24
20	0.28	0.37	0.16	0.17	0.47	0.10	0.11	0.72	0.30
21	0.43	0.24	0.33	0.20	0.28	0.05	0.09	0.25	0.23
22	0.37	0.26	0.18	0.19	0.29	0.02	0.04	0.40	0.22
23	0.65	0.11	0.30	0.11	0.53	0.07	0.02	0.21	0.25
24	0.59	0.26	0.15	0.15	0.19	0.05	0.03	0.21	0.20
25	0.37	0.25	0.22	0.11	0.09	0.02	0.07	0.27	0.18
26	0.43	0.34	0.25	0.15	0.09	0.06	0.03	0.90	0.28
27	0.17	0.20	0.16	0.25	0.13	0.04	0.04	0.27	0.16
28	0.20	0.12	0.25	0.08	0.14	0.06	0.02	0.04	0.11
29	0.12	0.06	0.07	0.09	0.18	0.06	0.08	0.19	0.11
30	0.29	0.28	0.08	0.04	0.05	0.06	0.09	0.53	0.18
31	0.34	0.23	0.07	0.01	0.04	0.06	0.09	0.09	0.12
32	0.26	0.15	0.24	0.05	0.09	0.02	0.09	0.43	0.17
33	0.11	0.23	0.14	0.11	0.06	0.03	0.03	0.20	0.11
34	0.10	0.03	0.24	0.05	0.08	0.07	0.04	0.10	0.09
35	0.11	0.09	0.10	0.10	0.12	0.11	0.10	0.08	0.09

Table 5.7. Annual estimates of sablefish total mortality rates (Z) from Virtual Population Analysis (M=0.1, Terminal F=0.1).

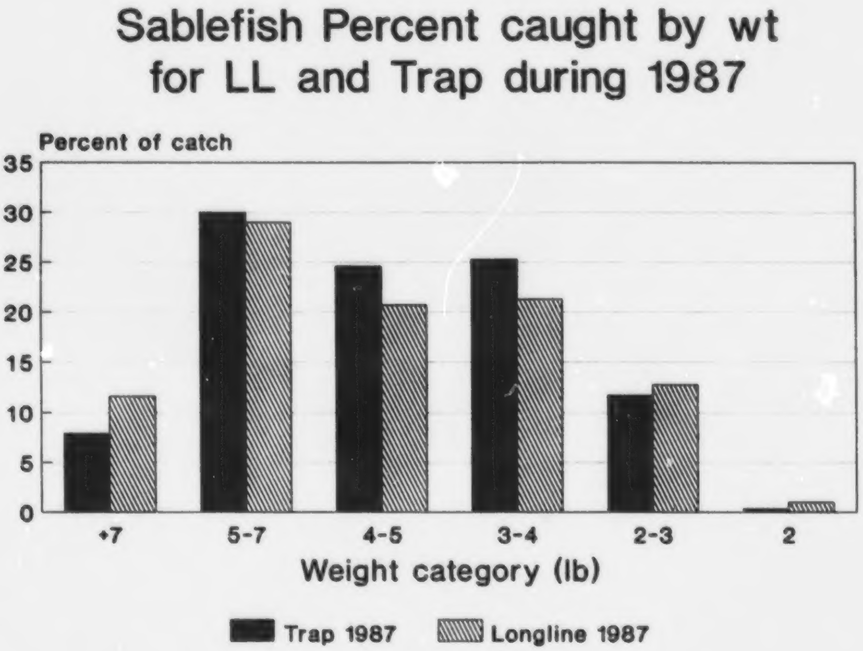
Age					Year				
	1979	1980	1981	1982	1983	1984	1985	1986	1987
5	0.10	0.13	0.15	0.17	0.14	0.17	0.14	0.15	0.14
6	0.10	0.18	0.17	0.19	0.30	0.18	0.18	0.20	0.19
7	0.11	0.21	0.22	0.23	0.27	0.34	0.26	0.19	0.23
8	0.10	0.26	0.16	0.31	0.28	0.21	0.38	0.23	0.24
9	0.11	0.22	0.23	0.35	0.33	0.32	0.39	0.26	0.28
10	0.15	0.25	0.21	0.42	0.51	0.32	0.29	0.23	0.30
11	0.16	0.32	0.24	0.42	0.41	0.41	0.31	0.26	0.32
12	0.17	0.32	0.32	0.39	0.49	0.31	0.17	0.33	0.31
13	0.22	0.35	0.25	0.48	0.42	0.39	0.19	0.54	0.35
14	0.29	0.36	0.27	0.32	0.63	0.30	0.43	0.47	0.38
15	0.27	0.34	0.35	0.45	0.47	0.45	0.29	0.50	0.39
16	0.32	0.45	0.31	0.35	0.34	0.21	0.22	0.48	0.34
17	0.41	0.42	0.35	0.27	0.61	0.18	0.14	0.66	0.38
18	0.39	0.32	0.31	0.39	0.38	0.15	0.17	0.24	0.29
19	0.49	0.35	0.28	0.31	0.63	0.31	0.16	0.22	0.34
20	0.38	0.47	0.26	0.27	0.57	0.20	0.21	0.82	0.40
21	0.53	0.34	0.43	0.30	0.38	0.15	0.19	0.35	0.33
22	0.47	0.36	0.28	0.29	0.39	0.12	0.14	0.50	0.32
23	0.75	0.21	0.40	0.21	0.63	0.17	0.12	0.31	0.35
24	0.69	0.36	0.25	0.25	0.29	0.15	0.13	0.31	0.30
25	0.47	0.35	0.32	0.21	0.19	0.12	0.17	0.37	0.28
26	0.53	0.44	0.35	0.25	0.19	0.16	0.13	1.00	0.38
27	0.27	0.30	0.26	0.35	0.23	0.14	0.14	0.37	0.26
28	0.30	0.22	0.35	0.18	0.24	0.16	0.12	0.14	0.21
29	0.22	0.16	0.17	0.19	0.28	0.16	0.18	0.29	0.21
30	0.39	0.38	0.18	0.14	0.15	0.16	0.19	0.63	0.28
31	0.44	0.33	0.17	0.11	0.14	0.16	0.19	0.19	0.22
32	0.36	0.25	0.34	0.15	0.19	0.12	0.19	0.53	0.27
33	0.21	0.33	0.24	0.21	0.16	0.13	0.13	0.30	0.21
34	0.20	0.13	0.34	0.15	0.18	0.17	0.14	0.20	0.19
35	0.21	0.19	0.20	0.20	0.22	0.21	0.20	0.18	0.19

Table 5.8. Annual exploitation rates (nos. caught/nos. in the stock) by age for sablefish from Virtual Population Analysis (M=0.1, Terminal F=0.1).

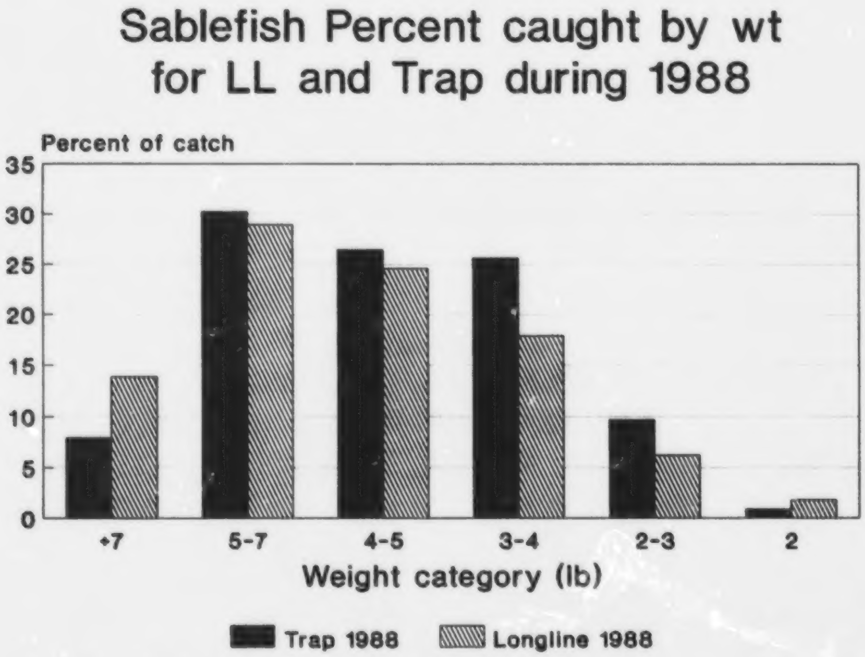
					Year				
Age	1979	1980	1981	1982	1983	1984	1985	1986	1987
5	0.00	0.03	0.05	0.06	0.04	0.06	0.04	0.04	0.04
6	0.01	0.08	0.07	0.09	0.17	0.07	0.08	0.09	0.08
7	0.01	0.10	0.11	0.12	0.15	0.20	0.15	0.08	0.12
8	0.00	0.14	0.05	0.18	0.16	0.10	0.23	0.12	0.13
9	0.01	0.11	0.12	0.21	0.20	0.19	0.24	0.14	0.15
10	0.05	0.13	0.10	0.26	0.32	0.19	0.16	0.12	0.17
11	0.06	0.19	0.13	0.26	0.26	0.25	0.18	0.14	0.18
12	0.06	0.19	0.19	0.24	0.31	0.17	0.06	0.20	0.18
13	0.10	0.21	0.13	0.30	0.26	0.24	0.08	0.34	0.21
14	0.17	0.22	0.15	0.19	0.40	0.17	0.27	0.30	0.24
15	0.15	0.20	0.21	0.28	0.30	0.28	0.17	0.31	0.24
16	0.19	0.28	0.18	0.22	0.20	0.09	0.11	0.30	0.20
17	0.25	0.26	0.21	0.15	0.38	0.07	0.03	0.41	0.23
18	0.24	0.19	0.18	0.24	0.23	0.04	0.07	0.12	0.17
19	0.31	0.21	0.16	0.17	0.39	0.18	0.06	0.11	0.21
20	0.24	0.29	0.15	0.15	0.35	0.09	0.09	0.49	0.25
21	0.34	0.20	0.27	0.17	0.24	0.05	0.08	0.21	0.20
22	0.30	0.22	0.16	0.16	0.24	0.02	0.03	0.31	0.19
23	0.46	0.10	0.24	0.10	0.39	0.06	0.02	0.18	0.21
24	0.43	0.22	0.13	0.13	0.17	0.05	0.03	0.18	0.18
25	0.30	0.21	0.19	0.10	0.09	0.02	0.07	0.23	0.15
26	0.34	0.27	0.21	0.13	0.08	0.06	0.02	0.57	0.23
27	0.15	0.17	0.14	0.21	0.12	0.03	0.04	0.22	0.14
28	0.17	0.10	0.21	0.07	0.13	0.05	0.02	0.04	0.10
29	0.11	0.06	0.06	0.08	0.16	0.06	0.07	0.16	0.10
30	0.24	0.24	0.07	0.03	0.05	0.06	0.08	0.39	0.16
31	0.28	0.19	0.06	0.01	0.04	0.06	0.08	0.08	0.10
32	0.22	0.14	0.20	0.05	0.08	0.02	0.08	0.34	0.15
33	0.10	0.20	0.13	0.10	0.05	0.03	0.03	0.17	0.10
34	0.09	0.03	0.20	0.05	0.08	0.07	0.03	0.09	0.08
35	0.10	0.09	0.09	0.09	0.11	0.10	0.09	0.07	0.08

Table 5.9. Annual estimates of sablefish numbers in stock, numbers landed, exploitation rates, mean F and Z values, ages 5-35, from Virtual Population Analysis (M=0.1, Terminal F=0.1).

Year	Nos. in stock	No. landed	Exploitation rate	Mean F	Mean Z
1979	7373510	1054133	0.14	0.22	0.32
1980	6056615	992847	0.16	0.20	0.30
1981	5348597	665010	0.12	0.17	0.27
1982	6462301	847237	0.13	0.17	0.27
1983	7779097	1111158	0.14	0.24	0.34
1984	9034107	909070	0.10	0.12	0.22
1985	9691164	1018284	0.11	0.10	0.20
1986	10413660	1018916	0.10	0.27	0.37
1987	11183265	1164299	0.10	0.19	0.29



Sablefish Percent caught by wt for LL and Trap during 1987



Sablefish Percent caught by wt for LL and Trap during 1988

Fig. 5.1. Percent of sablefish caught by weight category and gear for 1987 and 1988.

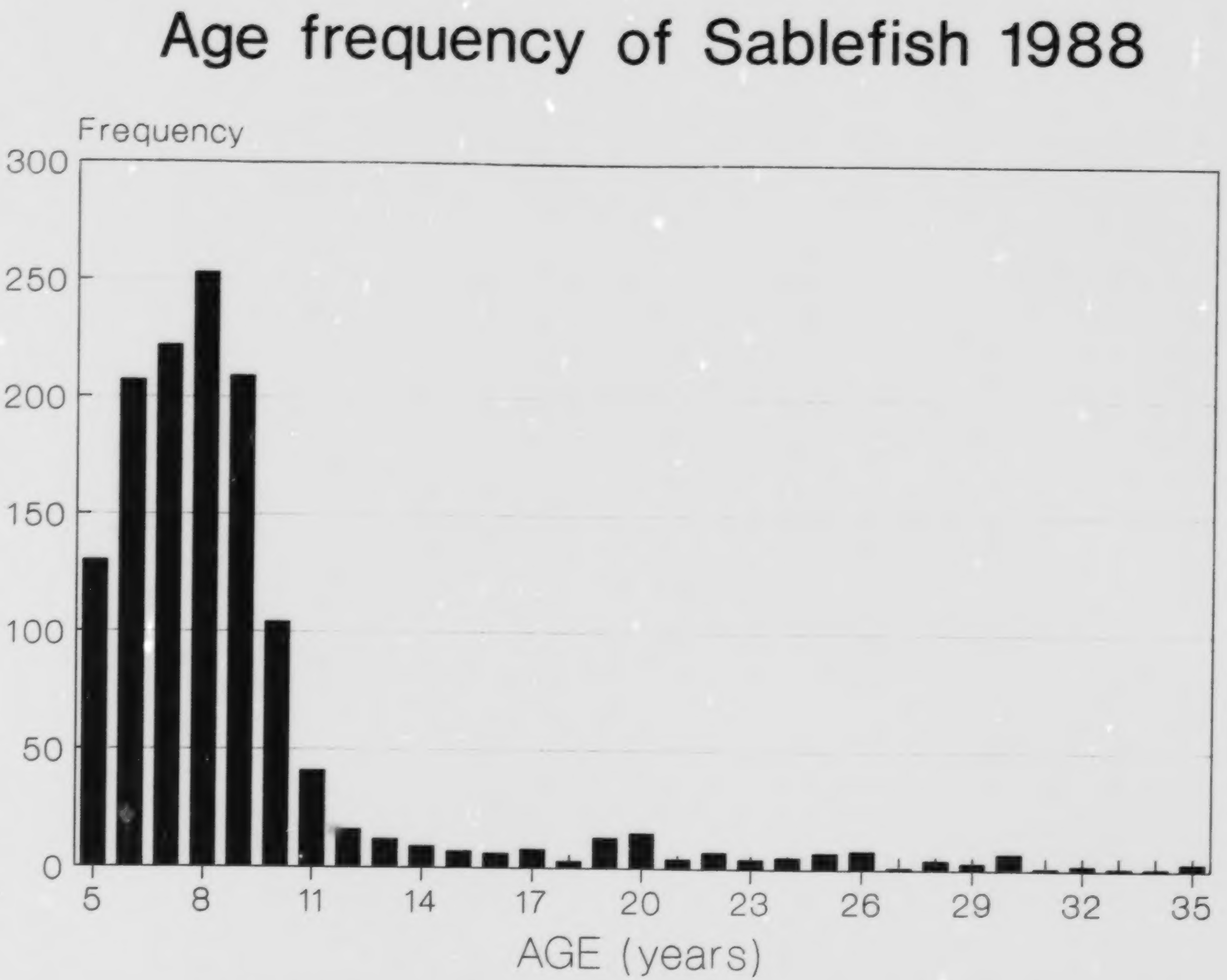


Fig. 5.2. Age frequency of commercial trap catches of sablefish during 1987 off the west coast of Canada.

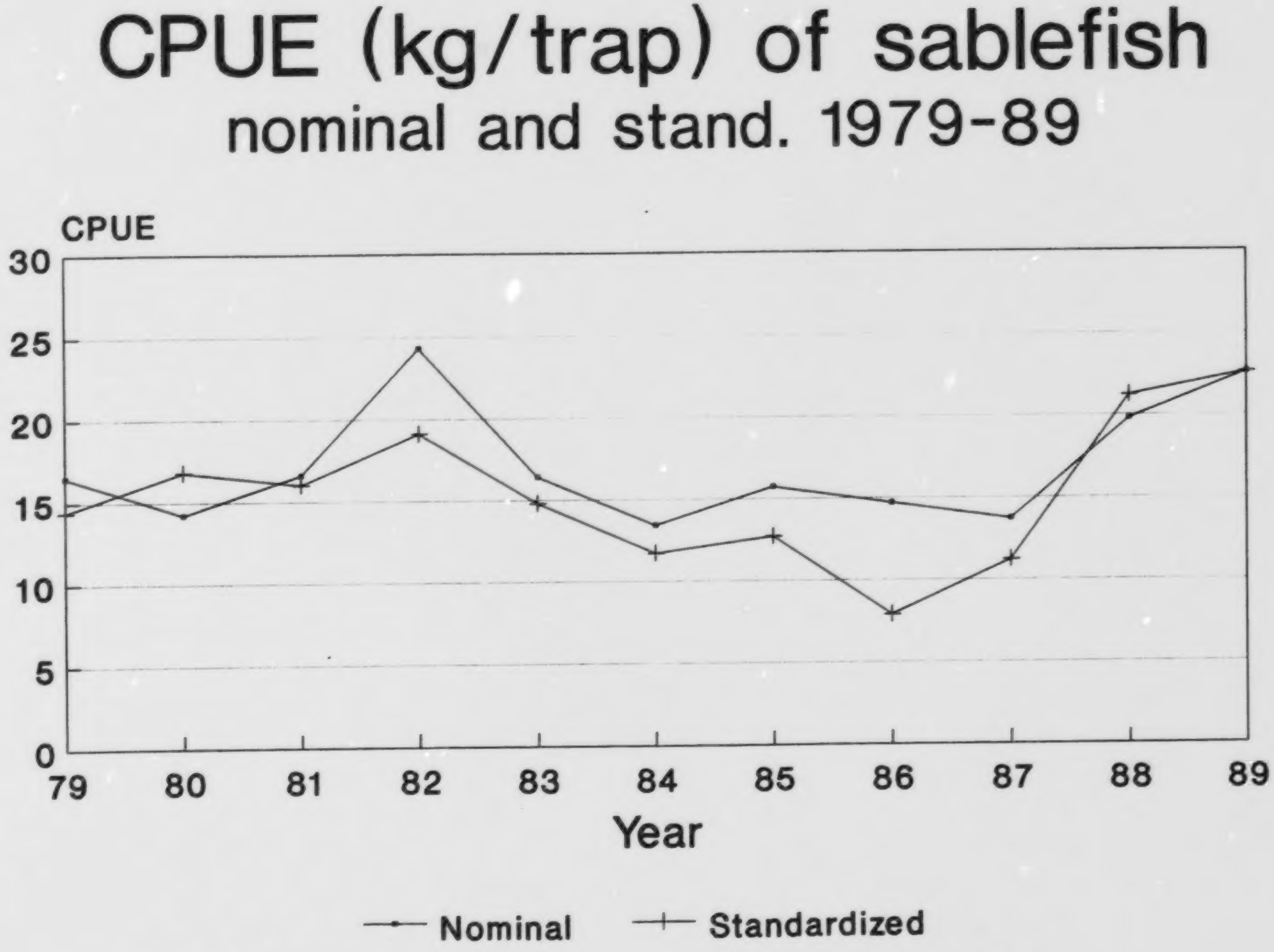


Fig. 5.3. Nominal and standardized CPUE (kg/trap) values of sablefish from 1979 to 1989.

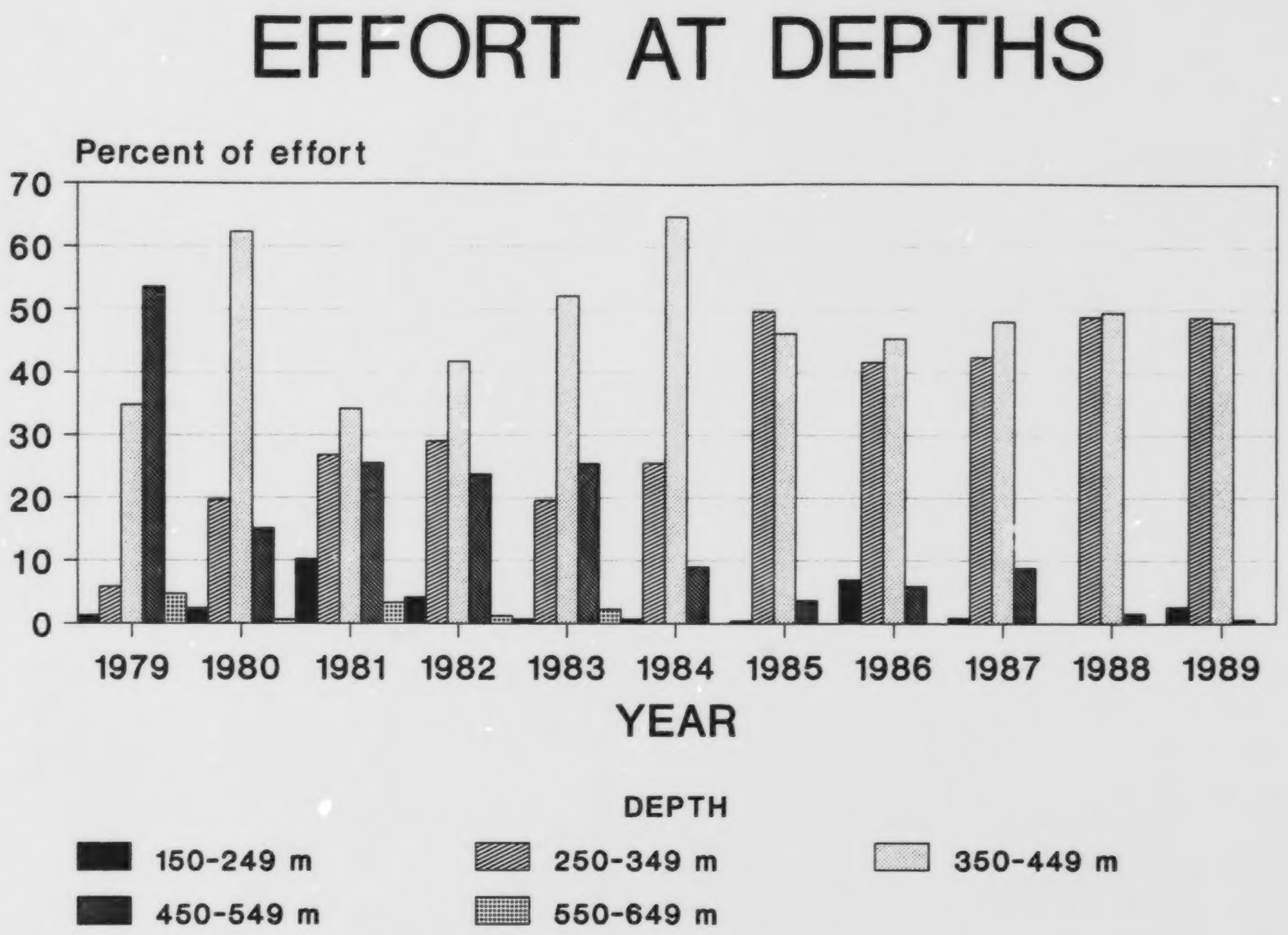


Fig. 5.4. Distribution of sablefish trap effort by average depth, 1979-1989.

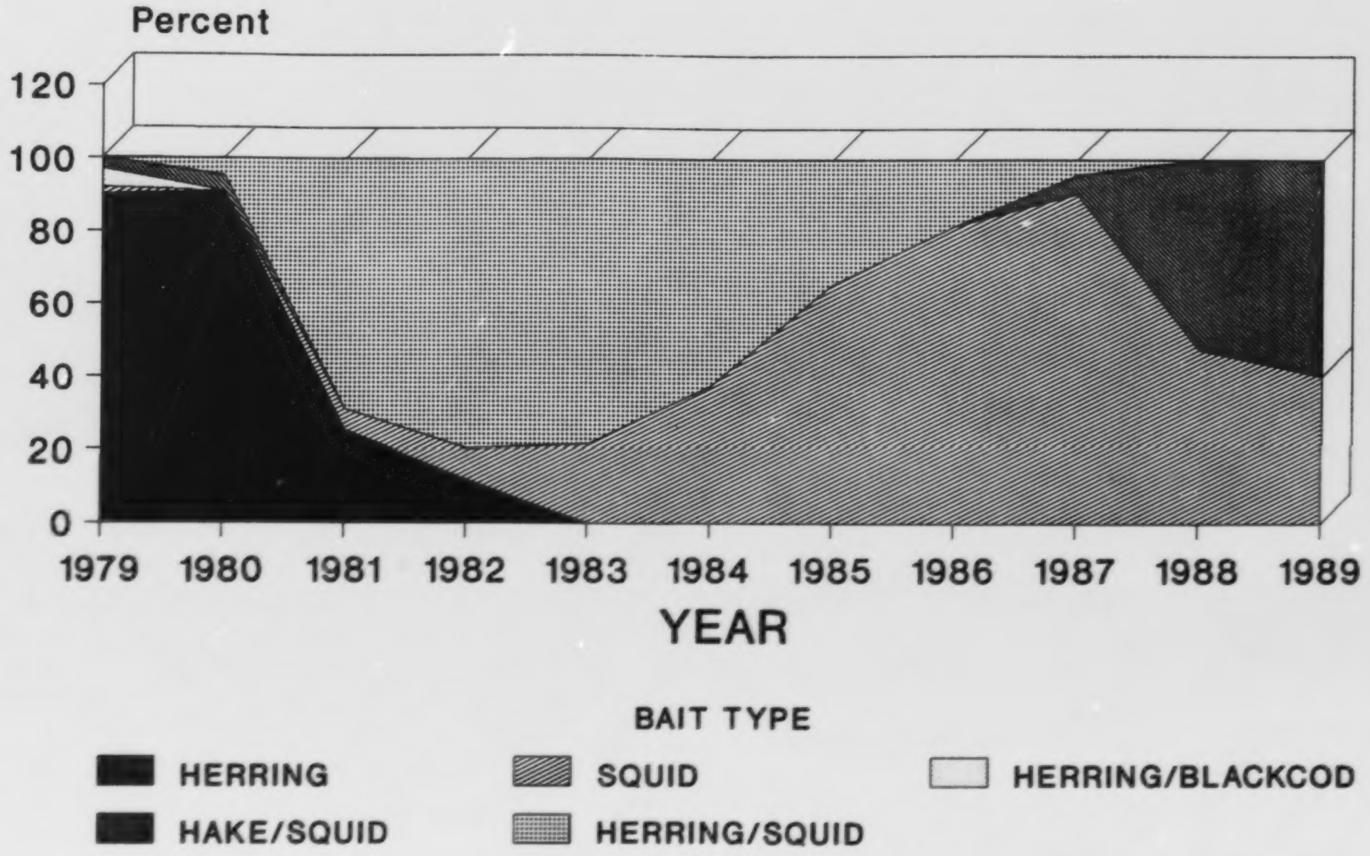


Fig. 5.5. Percent occurrence of bait type by year for the sablefish trap fishery.

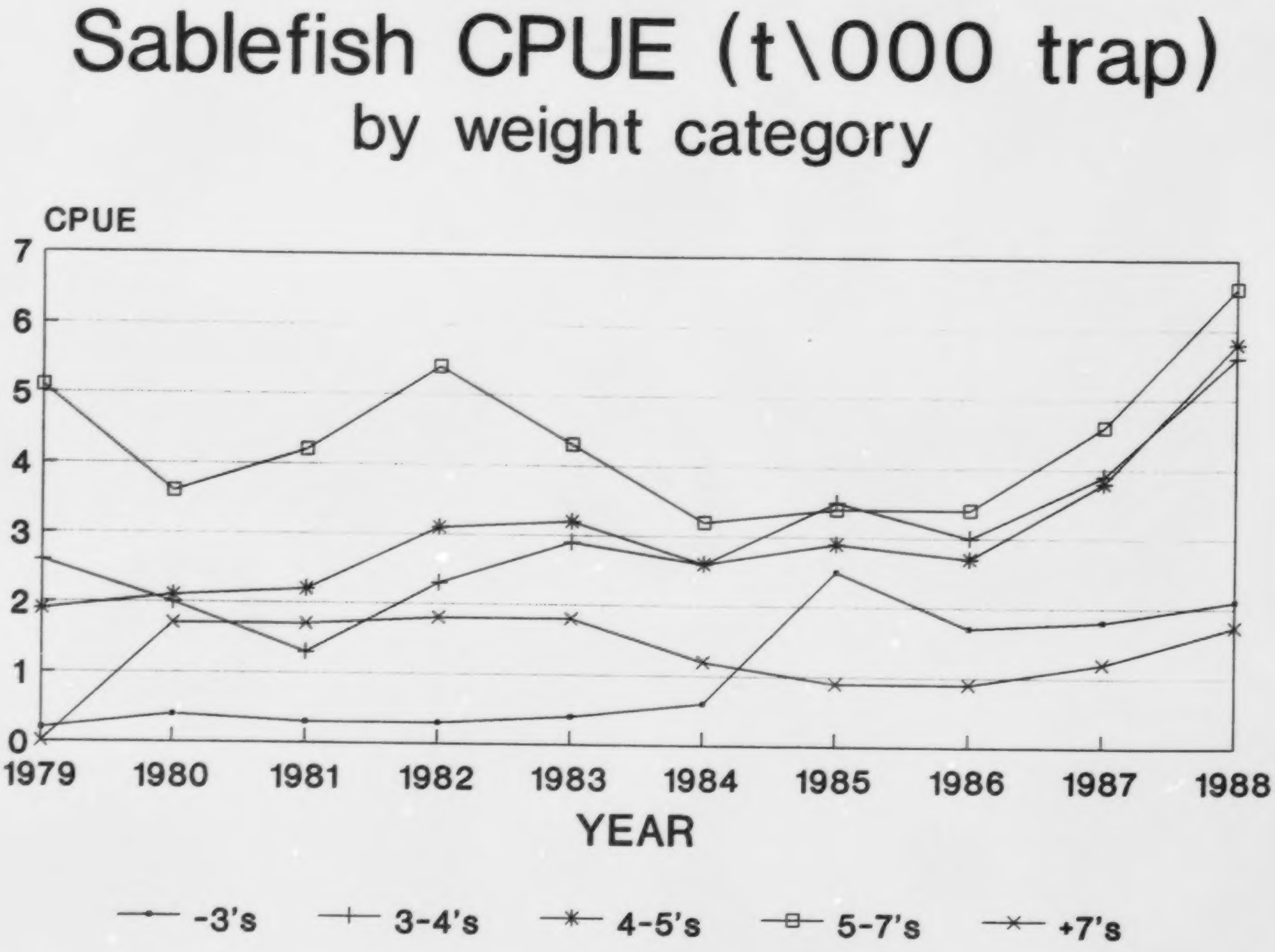


Fig. 5.6. Sablefish CPUE (t/1000 traps) by weight (lb) category for years 1979-1938.

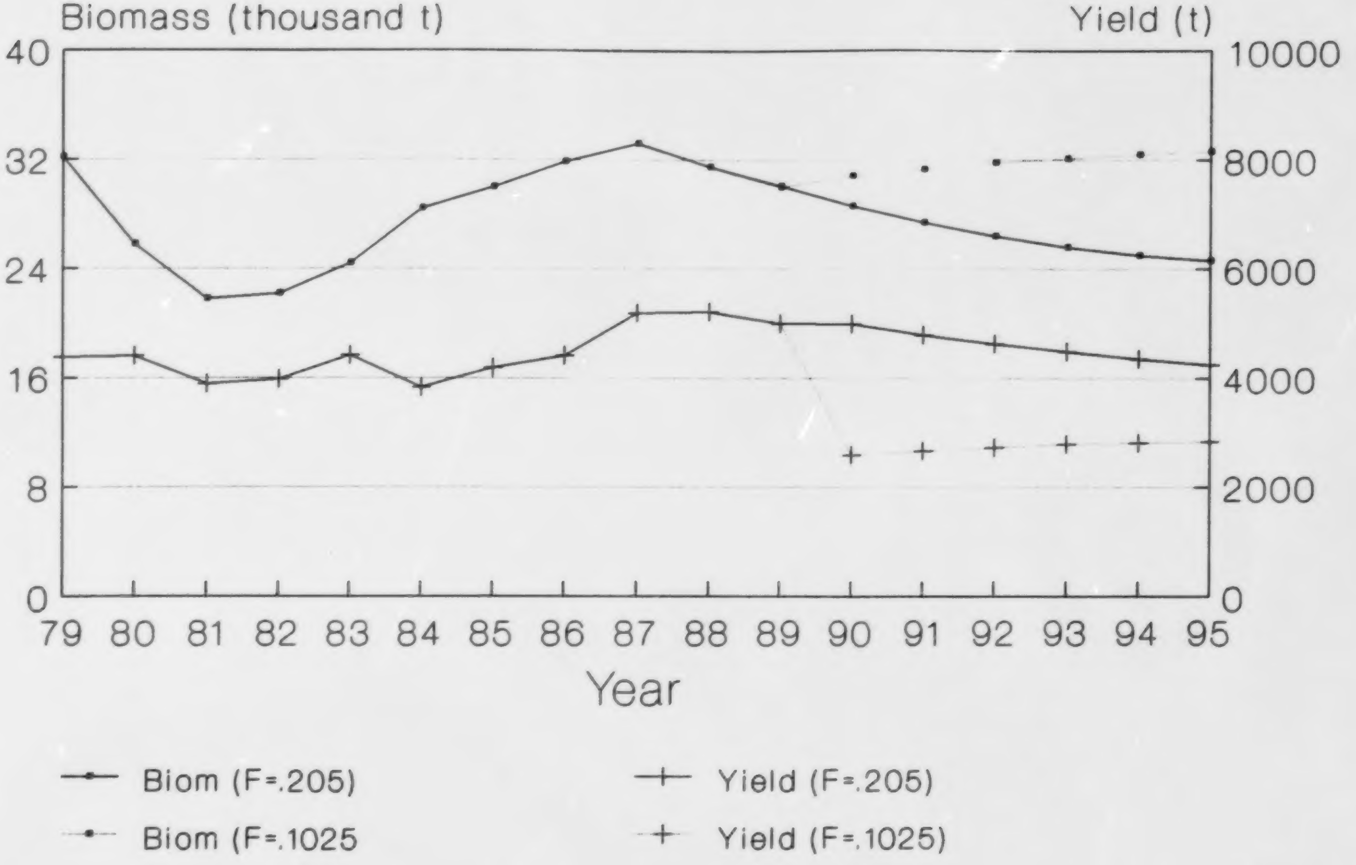


Fig. 5.7. Forward simulation of sablefish recruited biomass and yield at fishing rates (F) of 0.205 and 0.1025, assuming average recruitment beyond 1987.

6.0 PACIFIC HAKE

by M. W. Saunders,
L. J. Richards and
A. V. Tyler

6.1. Coastwide

Yield options are not proposed on a coastwide basis.

6.2. Strait of Georgia

6.2.1. Introduction

Pacific hake are the most abundant resident fish in the Strait of Georgia. Exploitation of the resident stocks has been increasing since the inception of the fishery in 1978. The proximity of the stocks to land-based processing, absence of the parasite Kudoa paniformes which is responsible for the rapid degradation of the flesh found in offshore Pacific hake, and the potential for harvesting roe from the large spawning concentration has made this an increasingly important fishery.

6.2.2 Landing Statistics

During 1988, a total of 5895 t was landed from the Strait of Georgia, a decrease of 35.4% over 1987 landings (Table 6.1). This decrease is a result of reduced market demand. In 1988, the effort was spread out over several quarters, a change from the predominantly second quarter landings of previous years (Table 6.1). Prior to 1986, most of the catch came from Minor Area 17. In 1986, exploitation shifted from Minor Area 17 to Minor Area 29, a trend which continued through to 1988 with 77.3% of the catch taken from Minor Area 29 (Table 6.1).

6.2.3. General Biological Information

6.2.4. Condition of the Stock

CPUE increased from 8.019 t/hr in 1987, to 10.190 t/hr in 1988 (Table 6.2). This continues the trend in increasing CPUE since 1985 and suggests that the stock is increasing. Given the schooling behaviour of this species there is some concern that CPUE in t/hr may not be a good measure of abundance.

Hydroacoustic and swept-volume surveys first conducted in 1981 were repeated in 1988. The area surveyed in both years was from the Winchelsea Islands to Sand Heads. Although the survey area covers the majority of the spawning hake stock, small concentrations are found north and south of the area. Hence the biomass estimates are not an estimate of the entire Strait of Georgia. Timing of the surveys was comparable with all surveys taking place from mid-March to early April.

It was estimated from the 1988 hydroacoustic survey that biomass decreased to 73,300 t (95% C.L. 2,474 t) from 77,790 t (confidence limits unavailable). Similarly the swept-volume surveys indicated a decrease to 112,545 t (95% C.L 45,326 t) from 125,600 (95% C.L. 36,200). Given the overlap in confidence limits it is reasonable to suggest that the stock is presently at a level of abundance which is comparable to, or slightly below the 1981 level.

Regarding differences between hydroacoustic and swept-volume estimates, they are probably the result of target strength values used in the hydroacoustic calculations. The target strength value of -32 dB is considered conservative. A value of -35 dB used in U.S. agency surveys would produce estimates roughly two times greater.

Catch-at-age analysis has not changed from the previous assessment (Saunders and Shaw 1989). A general forward simulation model (Tyler 1982) adapted for Pacific hake, was used to project spawner biomass and yield into the future at varying levels of recruitment. The model is driven by numbers-at-age from virtual population analysis (VPA), numbers at age 2 recruiting over time and catches from 1979 to 1987.

6.2.5. Yield Options

The risk associated with the harvest levels results from the inability to predict the strength of incoming year-classes. The three levels of harvest presented are capable of sustaining the spawning stock biomass assuming low, average and high recruitment respectively. Higher risk implies a greater likelihood of depleting the stock in the event of poor recruitment.

Constant Yield

- Low risk sustainable	- 8000 t
- Sustainable	- 11000 t
- High risk sustainable	- 14000 t

6.3 West Coast Vancouver Island

6.3.1 Introduction

Offshore Pacific hake (Merluccius productus) are highly migratory fish that range from southern California to Queen Charlotte Sound. Hake are present in the Canadian zone from late spring until late fall when they migrate south to spawn off California. The portion of stock in Canadian waters is composed of predominantly larger, older females.

Since 1968, more Pacific hake have been landed than any other species in the groundfish fishery on Canada's west coast. Prior to 1977, the USSR caught the major percentage of hake in the Canadian zone, with Poland and Japan accounting for much smaller quantities. Since 1977, and the declaration of the 200 mile extended fishing zone, the fishery has been divided into domestic, joint venture, and foreign operations. These are the most rapidly developing fisheries on Canada's west coast with the projected yield in 1989 to equal the quota for the first time.

The stock assessment document produced by Dorn and Methot (1989) requires additional consideration before it is suitable for use by Canadian managers. The calculations do not suitably address the differences between the U.S. and Canadian hake age-class structures because of the way the data are combined (Dorn and Methot 1989, pp. 14-15, and elsewhere). In addition because Canadian survey data are still being analyzed, the assessment is dependent on U.S survey data that does not sample the Canadian zone adequately, and biases the assessment to express mainly the U.S. fishery.

6.3.2 Catch Statistics

Coastwide catches of Pacific hake have increased from 234,147 t in 1987 to 251,189 t in 1988 (Table 6.3). The all-nation-catch in the Canadian zone was 90,491 t in 1988, up considerably from 73,699 t in 1986. As in the past, most of the catch was sold directly to foreign processing vessels. Canadian catch from joint venture fisheries with Russian, Polish and Japanese fishermen increased slightly to 50,182 t in 1988, from 48,076 t in 1987 (Table 6.4). Domestic catches reported during 1988 totalled 594 t, down from 4,170 t in 1987 (Table 6.3, Table 6.4).

6.3.3 General Biological Information

The Canadian fishery continues to be supported by a series of strong year-classes (Fig. 6.1, Table 6.5). In particular, the 1977 and 1980 year-classes continue to contribute significantly representing 7.9% and 67.0% by number, respectively, of the 1988 catch. The strong 1984 year-class, present in the U.S. fishery for the previous two years, began to contribute to the Canadian fishery, representing 15.5% by number. The U.S. fishery was supported by the 1980 and 1984 year-classes (Table 6.5).

In a fishery dominated by a small number of year-classes it is desirable to have the ability to forecast the relative strength of recruitment based on pre-recruit abundance. In previous assessments, measures of catch per unit effort and percent occurrence of 0-age hake in mid-water trawl surveys, conducted by the California Department of Fish and Game off the

California coast over the last 20 years, were used. Unfortunately, these indices are no longer available. Fishery data (Table 6.5) and preliminary results of the 1989 triennial surveys (Dorn and Methot 1989) indicate that year-class strengths have been average to poor since the strong 1984 year-class.

6.3.4 Condition of the Stock

The approach taken in this assessment is similar to that of the previous one (Saunders and Shaw 1989., Hollowed et al. 1988), using catch-at-age analysis tuned to independent survey estimates to assess the current status of the stock, and an age-structured forward simulation model to examine long and short term yield options. However, the catch-at-age analysis used in this assessment is different and numerous details of the forward simulation have changed considerably.

Catch-at-age estimates for the U.S. fishery from 1978-88 were calculated using the method of Kimura (1989). Catch-at-age in the Canadian zone was calculated by using the ratio of number-at-age to the weight-at-age in the age sample times the total catch. The weight-at-age in the sample was the sum of the weights from individual fish as derived from length-weight relationships for males and females sampled in the given year. Canadian and U.S. catch-at-age were summed to provide coastwide estimates (Table 6.5).

The cohort analysis used in previous assessments was replaced by a form of the stock synthesis model developed by Methot (1986 and 1989a). The application of the model to the Pacific hake population is detailed in an appendix to the 1988 U.S. assessment (Hollowed et al. 1988) and this year's analysis is presented in Dorn and Methot (1989).

Briefly, the synthesis model is a separable catch-at-age analysis that is tuned to the survey biomass and survey estimates of age composition. As in the past, catch-at-age was modelled as a single fishery with the Can. and U.S. catch-at-age matrices combined. The model does, however, allow treatment of the Can. and U.S. catches as competing fisheries or as separate stocks and can model selectivity patterns relative to the combined or separated Can/U.S. populations.

The model simulates the population's history and compares the model's expected values with observations of the catch. The model uses as input, catch biomass and age composition from the two fisheries, survey biomass, and survey age composition. The goodness of fit to these observations is evaluated in terms of log likelihood. The model can estimate population age composition in each year, recruitment in each subsequent year, fishery age-specific selectivity factors, and age-specific selectivity by the survey. Year-specific fishing mortalities are not estimated as parameters but rather tuned to the level necessary to match the observed catch and biomass.

As in the previous assessment, an age-structured simulation model, utilizing information on mortality, growth, abundance (from the stock synthesis model) and recruitment (from the stock synthesis model), was used to produce long-term estimates of hake production and projected yields for 1990. The age-structured model is a modification of Walters' (1969) generalized model for fish populations. An instantaneous rate of natural mortality of 0.2 was used for all ages in both analyses.

Recruitment was assumed in previous assessments to be a function of temperature at the time of spawning. Bailey (1981) showed hake recruitment to be inversely correlated to wind driven Ekman transport on the spawning ground at the time of spawning. He further reasoned that offshore transport was positively correlated with the level of upwelling which in turn, was negatively correlated with sea surface temperature. Hence, years of 'cold' water temperatures were assumed to be years of low larval survival and conversely, years of 'warm' water temperatures were assumed to be years of higher larval survival. In long term runs, recruitment values were driven by the temperature time series from 1931 to 1982 and drawn from log-normal random distributions with means and variances equal to those of the respective warm and cold year recruitments.

This approach was considered to be inappropriate for a number of reasons outlined in Dorn and Methot (1989). The most critical was the fact that the high coefficient of variability in hake recruitment results in recruitments that may be 3-4 times larger than any actually observed. Consequently, a method was adopted that involved sampling with replacement from the actual recruitment time series. The recruitment time series was extended back to 1959 using stock synthesis estimates.

The model is run in two modes, equilibrium and look-ahead. The equilibrium model utilizes a theoretical fished population and is run over 1000 years to establish optimal levels of effort, where yield is maximized and the integrity of the stock preserved. Over the observed time series there is no evidence to suggest that a relationship between stock size and recruitment exists. Hence, it is difficult to determine a level of fishing that may result in stock collapse. In previous assessments, optimum effort was defined as the effort level that maximized yield and produced a spawner biomass below the lowest observed level (critical spawner biomass of 0.319 million t) 10% of the time. In this assessment a slightly different approach was taken to determine the critical level of spawner biomass, and as well, varying levels of risk were explored rather than the single arbitrary value of 10%.

The critical or cautionary spawning biomass level was taken as the 0.1 percentile of the distribution of spawning biomass from 10 replicate 1000 yr simulations of an unfished population. (Fig. 6.2). This level occurs at 398 thousand t. Risk was assessed by determining the probability that under a given fishing effort the spawning biomass will drop below the cautionary level of spawning biomass. Three levels of risk were examined. Under a low risk strategy the probability of falling below the cautionary spawning biomass is 0.05, moderate is 0.15 and high risk is 0.25. Dorn and Methot (1989) point out that while the numbers are arbitrary, they result in fishing mortality rates that correspond to other reference points commonly used to guide management decisions. Low risk options approach an F=M strategy, moderate risk levels are similar to those that would be calculated from surplus production estimates of MSY and the high risk level is similar to an F0.1 level.

A summary of parameter values used in the 1000-year runs is presented in Table 6.6. Runs were conducted under two possible management scenarios, constant effort and variable effort. The variable effort strategy is similar to that described by Shuter and Koonce (1985) as one which greatly reduces the risk of stock collapse when compared with constant catch or constant effort. The algorithm was constrained to limit maximum yield to 500,000 t. Fishing mortality in a given year was calculated as follows:

f_i = fishing mortality in year i
$= f_{opt}\,(SB_i \,/\, SB_{opt})$

Where,

f_{opt} = optimal fishing mortality
SB_{opt} =spawner biomass level at F_{opt}
SB_i = spawner biomass in year i

A summary of equilibrium run results is presented in Table 6.7. As in past investigations, the variable effort policy results in higher yields at a given level of risk. Managers should be aware that while yields are higher they also tend to fluctuate more as they are closely tied to the influx and departure of strong year-classes.

The optimal levels of effort and biomass were then used in look ahead simulations to make projections of future yields. The starting population in 1988 is the numbers-at-age from the stock synthesis analysis. Recruitment of the 1988, 1989 and 1990 year-classes provides some uncertainty in the yield projections. Four alternatives are considered and are presented in Table 6.8. The starting parameters for the look ahead runs are also presented in Table 6.8.

The results of 1990-92 catch projections under the various recruitment alternatives are presented in Table 6.9. The yield levels for 1990 range from 114 to 273 thousand t. The largest portion of the range (100 thousand t) is explained by the risk level, while the recruitment and effort strategy explain 20 and 12 thousand t, respectively. Managers should note that, if recruitment continues to be weak, the projected yields will decrease rapidly over the next several years.

The effect of the changes in the assessment from the previous analysis (Hollowed et al. 1988) was reported by Dorn and Methot (1989). They found that none of the changes altered the yield projections for 1990 by more than 7% and that the largest difference was due to the risk assessment. These risk levels are in turn dependent on the establishment of a new minimum spawning biomass combined with the variable expressing the percentage of time that the stock is arbitrarily allowed to be fished below this cautionary level. In previous years 319,000 t was the cautionary level, now modified upward to capture estimates of stock sizes in the 1960s that were inflated by the very large 1961 year-class. It is not clear that the new level of 398,000 t is truly more representative than, say, 200,000 t. Should the very large year-classes be put into an average that purports to address the question of what is the minimum allowable spawning biomass?

6.3.5 Canada-U.S. Division of Potential Yield

The analysis presented is conducted on a coastwide basis. A split stock model is under development which will facilitate exploration of the biological implications of varying harvest strategies on U.S. and Canadian components of the stock. Until this model is complete the appropriate method of splitting the available yield between Canadian and U.S. fisheries will be problematic.

In the U.S. assessment (Dorn and Methot 1989) the recommended U.S./Can. split in yield is 80/20 based on the projected numbers-at-age for 1990, the age-specific fractions migrating into the Canadian zone estimated using a logistic regression of the proportion (in number) at age from the triennial abundance surveys, and the fishery specific weight-at-age. There are a number of reasons that we feel this proportion underestimates the Canadian contribution to the total biomass. Given that the large 1984 year-class is only now approaching full recruitment to the Canadian fishery, intuitively, it does not seem appropriate to be decreasing yield in the Canadian zone.

The catch-at-age data are not consistent with the report that only 20% of the stock biomass is in the Canadian zone. Most of the Canadian catch is made up of age 6 and older fish. The U.S. catch for ages 6 through 10, inclusive, in 1988 was 106.81 million fish, while the Canadian catch for the same ages was 73.85 million fish (Table 6.5). That is the U.S. catch of these ages was only a factor of 1.44 times higher than the Canadian catch. If only 20% of the stock was in the Canadian zone is this difference plausible given that somewhat less fishing effort was expended in the Canadian zone (Dorn and Methot 1989, Appendix Table 2). For this to be true more of the stock must have been in the Canadian zone. This discrepancy may be due to a bias introduced by tuning the stock synthesis model to the U.S. survey biomass estimates.

The triennial surveys on which the split is based extend only to 49 degrees north latitude and miss a proportion of the Canadian biomass. Richards and Saunders (in prep) report that qualitative surveys extending to the northern tip of Vancouver Island indicate that at least 27.8% of the total biomass in the Canadian zone may be found north of the survey area. These surveys did not extend into Queen Charlotte Sound where commercial fishermen have encountered significant quantities of hake in recent years, indicating that the percentage may be even higher.

One final point regarding this issue is that the border region of the INPFC Vancouver Area is a region of high hake density and that the snapshot of biomass taken by the survey may not represent the typical distribution of this highly mobile species that is present in the area for up to six months.

We recommend splitting the yield using a method proposed by Richards and Saunders (in prep.) which is based on the relative biomass that would have been in the Canadian zone if no fishing had occurred. This analysis indicates that the proportion of unfished biomass in the Canadian zone based on tuned vulnerabilities is 28%. Tuned vulnerabilities are derived from the assumption that selectivities are similar for Canada and U.S. fisheries. This proportion could be as high as 58%, based on the 1983 survey data, indicating that future work should be directed at developing a more thorough understanding of stock distribution.

6.3.6 Yield Options

The yield options for the Canadian fishery for variable and constant effort levels are presented below with associated coastwide quotas in brackets. The available yields have been split using the 0.28 proportion discussed above.

The risk levels, as explained above, pertain to the probability of lowering the spawning stock size to a cautionary level below which the stock may not be able to recover. Given the evidence presented by Dorn and Methot (1989) we have chosen a recruitment scenario that represents the 1988 year-class as weak.

Variable effort:

Low risk sustainable - 32 (114) thousand t

Sustainable - 50 (180) thousand t

High risk sustainable - 70 (245) thousand t

Constant effort:

Low risk sustainable - 34 (123) thousand t

Sustainable - 50 (179) thousand t

High risk sustainable - 64 (230) thousand t

Another option is a maximum 20% reduction from the 1989 quota level, within the range of the reduction percentage suggested for the U.S. fishery (see PFMC Newsletter of September 26, 1989). This would mean that the 1990 quota would be 78,000 t. If the 398,000 t cautionary spawning biomass level is appropriate, then a stepwise approach like this, while probably acceptable in the first year, could jeopardize the spawning stock in the event of continued poor recruitment. However, since the strong 1984 year-class is just recruiting to the Canadian zone as 6-year-olds, the percentage reduction for the Canadian zone this year could be substantially less than the U.S. zone reduction, for example, 10%. This would give a quota of 84,000 t for 1990.

Table 6.1. Pacific hake landings (t), excluding dumped and discarded fish for the second quarter and whole year for Minor Areas 14, 17 and 29, and Major Area 4B (Strait of Georgia) during 1977-1988.

	1977		1978		1979		1980		1981		1982	
Region	Q2	Yr	Q2	Yr	Q2	Yr	Q2	Yr	Q2	Yr	Q2	Yr
Minor Area												
14	0	0	-	-	-	-	0	385	448	523	-	-
17	-	-	0	1	484	484	-	-	76	182	1927	2420
29	-	-	0	2	2	2	0	5	810	1434	0	12
Major Area												
4B	0	0	1	2	486	516	1	508	1364	2409	1927	2824

	1983		1984		1985		1986		1987		1988	
Region	Q2	Yr	Q2	Yr	Q2	Yr	Q2	Yr	Q2	Yr	Q2	Yr
Minor Area												
14	53	53	368	368	15	77	849	1209	686	796	0	3
17	2208	2240	805	1736	1700	3718	1073	1158	1216	1444	68	944
29	0	11	544	951	67	982	618	2296	3832	5852	1575	4559
Major Area												
4B	3078	3122	1717	3056	1827	4976	2540	5031	5811	9127	1643	5895

Table 6.2. Pacific hake landings, CPUE and effort from the Strait of Georgia (Major Area 4B), 1977-1988.

Year	Total catch (t)	CPUE[a] (t/hr)	Effort[b] (hr)
1977	.04	0	0
1978	2	0	0
1979	516	10.207	51
1980	508	4.583	111
1981	2409	8.937	270
1982	2824	4.796	589
1983	3121	4.465	699
1984	4599	6.780	678
1985	4976	4.448	1119
1986	5031	7.450	675
1987	9127	8.019	1138
1988	5895	10.190	579

[a] CPUE @ 25% qualification level.
[b] Effort = Total catch/CPUE.

Table 6.3. Annual catches of Pacific whiting (kt) in U.S. and Canadian management zones by foreign, joint venture (JV), and domestic fleets, 1966-1989.

	U.S.				Canada				
Year	Foreign	JV	Domestic	Total	Foreign	JV	Domestic	Total	Combined total
1966	137.000	0.000	0.000	137.000	0.700	0.000	0.000	0.700	137.700
1967	168.699	0.000	8.963	177.658	36.713	0.000	0.000	36.713	214.371
1968	60.660	0.000	0.159	60.819	61.361	0.000	0.000	61.361	122.180
1969	86.187	0.000	0.093	86.280	93.851	0.000	0.000	93.851	180.131
1970	159.509	0.000	0.066	159.575	75.009	0.000	0.000	75.009	234.584
1971	126.485	0.000	1.428	127.913	26.699	0.000	0.000	26.699	154.612
1972	74.093	0.000	0.040	74.133	43.413	0.000	0.000	43.413	117.546
1973	147.441	0.000	0.072	147.313	15.125	0.000	0.001	15.126	162.439
1974	194.108	0.000	0.001	194.109	17.146	0.000	0.004	17.150	211.259
1975	205.654	0.000	0.002	205.656	15.704	0.000	0.000	15.704	221.360
1976	231.331	0.000	0.218	231.549	5.972	0.000	0.000	5.972	237.521
1977	127.013	0.000	0.489	127.502	5.191	0.000	0.000	3.453	130.955
1978	98.827	0.856	0.689	98.372	3.453	1.814	0.000	6.464	104.836
1979	114.909	8.834	0.937	124.680	7.900	4.233	0.302	12.435	137.115
1980	44.023	27.537	0.792	72.352	5.273	12.214	0.097	17.584	89.936
1981	70.365	43.556	0.839	114.760	3.919	17.159	3.283	24.361	139.121
1982	7.089	67.464	1.024	75.577	12.479	19.676	0.002	32.155	107.732
1983	0.000	72.100	1.050	73.150	13.117	27.657	0.000	40.774	113.924
1984	14.722	78.889	2.721	96.382	13.203	28.906	0.000	42.109	138.491
1985	49.853	31.692	3.894	85.439	10.533	13.237	1.192	24.962	110.401
1986	69.861	81.640	3.463	154.964	23.743	30.136	1.774	55.653	210.617
1987	49.656	105.997	4.795	160.448	21.453	48.076	4.170	73.699	234.147
1988	18.041	135.781	6.876	160.698	39.715	50.182	0.594	90.491	251.189
1989	0.000	204.038[a]	-	-	-	-	-	-	-
Mean 66-88				128.101				35.471	163.572

[a] Provisional JV catch as of 7/18/89.

Table 6.4. Total landings (t) of offshore hake by foreign and domestic fishery off Canada (Area 3C) during 1978-1986.

		Total landings (t)			
Year	Nations	National	Joint venture	Domestic	Total
1978	Poland	589	1,814		
	USSR	700	0		
	Japan	3,364	0		
	Total	4,653	1,814		6,467
1979	Poland	4,263	3,102		
	USSR	0	1,131		
	Japan	3,637	0		
	Total	7,900	4,233	302	12,435
1980	Poland	4,456	4,560		
	USSR	78	4,300		
	Japan	817	0		
	Greece	0	3,355		
	Total	5,351	12,214	96	17,661
1981	Poland	3,189	4,779		
	USSR	227	7,342		
	Japan	187	0		
	Greece	0	49,827		
	Total	3,603	17,048	4,440	25,091
1982	Poland	10,357	10,222		
	USSR	0	9,391		
	Japan	2,237	0		
	Total	12,594	19,613	2	32,209

Table 6.5. Catch-at-age (million) for the Pacific whiting fisheries, 1978-1988. Separate tables are given for the U.S. fisheries, the Canadian fisheries and the fisheries of the two nations combined. These numbers include the foreign, joint venture and domestic fisheries. The catch-at-age estimates for the U.S. fishery were revised using the procedure described in the text (Dorn and Methot 1989).

U.S. fisheries:

Year	1	2	3	4	5	6	7	Age 8	9	10	11	12	13	14	15	Total
1978	0.01	0.02	4.56	8.58	51.87	9.48	20.32	38.57	5.74	2.48	1.28	0.52	0.20	0.05	0.01	143.69
1979	0.00	4.34	8.74	17.41	10.15	48.01	15.47	29.48	20.82	4.25	1.70	0.50	0.22	0.05	0.03	161.16
1980	0.00	0.13	24.67	2.16	6.90	7.16	20.11	9.57	11.99	9.92	1.74	1.35	1.01	0.59	0.14	97.42
1981	13.38	1.25	2.30	97.62	6.89	9.64	6.77	23.33	6.26	7.24	7.05	0.95	0.48	0.12	0.13	183.43
1982	0.00	27.51	1.93	1.57	57.88	5.02	5.78	5.02	11.96	2.43	2.53	4.64	0.34	0.13	0.03	126.77
1983	0.00	0.00	86.60	7.22	3.63	36.79	4.68	3.72	3.32	5.24	5.24	1.00	1.00	0.16	0.14	155.12
1984	0.00	0.00	2.59	164.97	7.18	5.18	17.54	2.17	1.24	0.82	0.82	0.21	0.20	0.31	0.03	203.78
1985	2.27	0.55	1.32	12.36	113.50	9.74	4.30	6.75	0.61	0.34	0.34	0.36	0.00	0.00	0.00	152.34
1986	0.00	62.92	12.88	1.85	9.34	171.79	21.55	10.76	12.45	1.53	1.53	0.38	0.79	0.15	0.05	307.49
1987	0.00	0.00	124.20	6.58	1.68	2.72	151.56	7.89	3.09	14.87	14.87	0.15	0.15	1.25	0.00	314.71
1988	0.00	1.22	1.31	172.76	8.02	1.40	2.60	96.93	5.16	0.72	0.72	0.15	0.24	0.00	0.65	299.49

Canadian fisheries:

Year	1	2	3	4	5	6	7	Age 8	9	10	11	12	13	14	15	Total
1978	0.00	0.00	0.00	0.20	0.35	0.28	1.06	1.31	1.12	0.62	0.48	0.21	0.18	0.09	0.00	5.90
1979	0.00	0.00	0.00	0.21	0.62	1.30	1.14	2.10	3.02	1.10	0.79	0.37	0.25	0.17	0.12	11.18
1980	0.00	0.00	0.00	0.00	0.47	0.62	2.46	0.92	1.18	6.74	1.27	0.62	0.62	0.20	0.00	15.07
1981	0.00	0.00	0.00	1.01	0.27	1.41	1.38	4.28	0.85	2.36	6.18	1.49	0.60	0.85	0.00	20.66
1982	0.00	0.00	0.00	0.69	13.35	1.10	1.44	1.41	4.41	1.00	0.78	6.04	0.59	0.47	0.00	31.27
1983	0.00	0.06	14.02	1.03	1.80	32.15	1.29	1.87	1.67	5.59	0.77	0.26	3.41	0.26	0.13	64.30
1984	0.00	0.00	1.11	13.27	1.73	9.26	20.86	2.04	2.35	1.54	4.81	0.93	0.80	2.65	0.37	61.71
1985	0.00	0.06	0.06	2.45	8.03	1.65	3.25	9.62	0.49	0.55	0.55	1.65	0.37	0.00	1.59	30.33
1986	0.00	0.14	0.14	0.28	3.97	38.41	2.41	2.41	11.48	1.28	0.57	0.99	1.42	0.43	1.42	65.33
1987	0.00	0.00	0.90	0.60	0.15	2.56	70.71	2.86	2.86	10.38	0.60	0.45	1.20	0.90	1.20	95.38
1988	0.00	0.00	0.31	15.28	0.62	1.13	2.36	66.66	2.26	1.44	7.90	0.51	0.21	0.21	0.62	99.48

Table 6.5 (cont'd)

	Combined fisheries:							Age								
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
1978	0.01	0.02	4.56	8.78	52.21	9.76	21.38	39.88	6.86	3.10	1.76	0.73	0.38	0.14	0.01	149.58
1979	0.00	4.34	8.74	17.52	10.76	49.31	16.61	31.58	23.83	5.34	2.49	0.87	0.46	0.22	0.15	172.34
1980	0.00	0.13	24.67	2.16	7.36	7.77	22.57	10.49	13.16	16.65	3.00	1.97	1.62	0.78	0.14	112.49
1981	13.38	1.25	2.30	98.63	7.16	11.05	8.16	27.60	7.11	9.60	13.23	2.44	1.08	0.97	0.13	204.09
1982	0.00	27.51	1.93	2.25	71.24	6.11	7.22	6.43	16.37	3.43	3.31	10.67	0.94	0.60	0.03	158.04
1983	0.00	0.06	100.61	8.25	5.43	68.93	5.96	5.58	4.99	10.83	2.39	1.26	4.41	0.42	0.27	219.42
1984	0.00	0.00	3.71	178.24	8.91	14.43	38.39	4.20	3.58	2.36	6.15	1.14	1.00	2.97	0.40	265.49
1985	2.27	0.61	1.38	14.81	121.52	11.39	7.55	16.37	1.10	0.89	0.79	2.02	0.37	0.00	1.59	182.67
1986	0.00	63.06	13.02	2.13	13.31	210.20	23.55	13.17	23.93	2.80	1.62	1.37	2.20	0.58	1.46	372.82
1987	0.00	0.00	125.10	7.18	1.83	5.28	222.27	10.74	5.95	25.25	1.17	0.60	1.35	2.15	1.20	410.09
1988	0.00	1.22	1.62	188.05	8.64	2.53	4.96	163.59	7.42	2.15	16.22	0.67	0.44	0.21	1.26	398.96

Table 6.6. Parameter values for the age-structured simulation model used to estimate long-term yield (from Dorn and Methot 1989).

Number of age-classes 13

Age at first vulnerability to the fishery 2

Age	2	3	4	5	6	7	8	9	10	11	12	13	14
USWT	285.5	404.6	493.9	571.4	625.4	673.2	723.2	769.2	812.4	866.6	924.1	972.4	1029.1
CANWT	309.5	489.1	618.0	703.0	767.3	803.6	871.7	928.8	949.2	1015.8	1075.0	1108.4	1117.0
POPWT	249.9	387.6	494.0	589.6	659.5	723.1	784.4	845.0	894.0	946.3	997.2	1042.6	1083.1
SELECT	0.089	0.195	0.563	0.688	0.874	0.925	1.000	0.749	0.739	0.280	0.237	0.053	0.024
MATURE	0.000	0.500	0.750	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
PROPFEM	0.480	0.501	0.512	0.520	0.524	0.526	0.529	0.536	0.539	0.544	0.553	0.561	0.568
USCAN	0.004	0.012	0.032	0.070	0.122	0.180	0.234	0.275	0.302	0.317	0.324	0.330	0.338
POPINIT	0.100	0.013	2.635	0.081	0.013	0.004	0.727	0.015	0.002	0.099	0.004	0.008	0.165
NMORT	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200

Definitions:

USWT	United States fishery weight at age (kg)
CANWT	Canadian fishery weight at age (kg)
POPWT	Population weight at age (kg)
SELECT	Combined fishery selectives estimated by the stock synthesis model
MATURE	Proportion of sexually mature females
PROPFEM	Proportion by weight of females in the population
USCAN	Proportion of fish in the Canadian zone
POPINIT	Initial population vector (billions)
NMORT	Natural mortality rate

Table 6.7. Sustainable yield for different management policies estimated by averaging the results of 10 replicate simulations of the fishery of 1,000 years each. SB_{opt} used in the variable effort algorithm is the mean spawning biomass where the probability is 0.15 that the spawning biomass goes below the cautionary level (from Dorn and Methot 1989).

	F-opt	Total yield (kt)	CV	U.S. yield (kt)	CV	SB-opt (kt)	Spawn. biom. (kt)	CV	Pcnt below SB-caut	Pcnt at yield cap
						Constant effort policy				
Low risk	0.18	178	48.9	150	50.3	--	949	41.3	5.0	0.2
Moderate risk	0.27	214	50.7	184	52.3	--	767	46.7	15.0	1.9
High risk	0.36	244	50.2	213	51.5	--	666	49.8	25.0	4.8
						Variable effort algorithm				
Low risk	0.21	205	68.0	177	70.1	767	817	40.3	5.0	8.0
Moderate risk	0.35	237	64.3	207	66.5	767	687	43.3	15.0	12.8
High risk	0.50	251	63.1	221	65.2	767	615	47.2	25.0	16.2

Table 6.8. Summary of information used for the short-term yield forecasts of the Pacific whiting resource (from Dorn and Methot 1989).

Beginning of the year population abundance (billion)

Year	2	3	4	5	6	7	8	9	10	11	12	13	14
1988	0.100	0.013	2.635	0.081	0.013	0.004	0.727	0.015	0.002	0.099	0.004	0.008	0.165
1989	0.137	0.080	0.010	1.885	0.056	0.009	0.003	0.468	0.020	0.001	0.076	0.003	0.141
1990	--	0.108	0.061	0.007	1.188	0.033	0.005	0.001	0.288	0.006	0.001	0.057	0.117

Weight-at-age (kg)

Age	2	3	4	5	6	7	8	9	10	11	12	13	14
U.S.	0.300	0.395	0.465	0.519	0.558	0.573	0.610	0.648	0.696	0.731	0.798	0.845	0.873
Can.	0.314	0.457	0.566	0.643	0.692	0.706	0.768	0.801	0.827	0.877	0.919	0.943	0.940
Pop.	0.266	0.375	0.456	0.522	0.571	0.599	0.635	0.682	0.736	0.780	0.833	0.887	0.944

1988 estimated yield: 251 kt
1989 expected yield: 303 kt

1989 beginning of year spawning biomass: 829 kt
1990 beginning of year spawning biomass: 599 kt

Recruitment scenarios

A:	1988 year-class	strong
	1989 year-class	weak
	1990 year-class	weak
B:	1988 year-class	weak
	1989 year-class	strong
	1990 year-class	weak
C:	1988 year-class	weak
	1989 year-class	weak
	1990 year-class	strong
D:	1988 year-class	weak
	1989 year-class	weak
	1990 year-class	weak

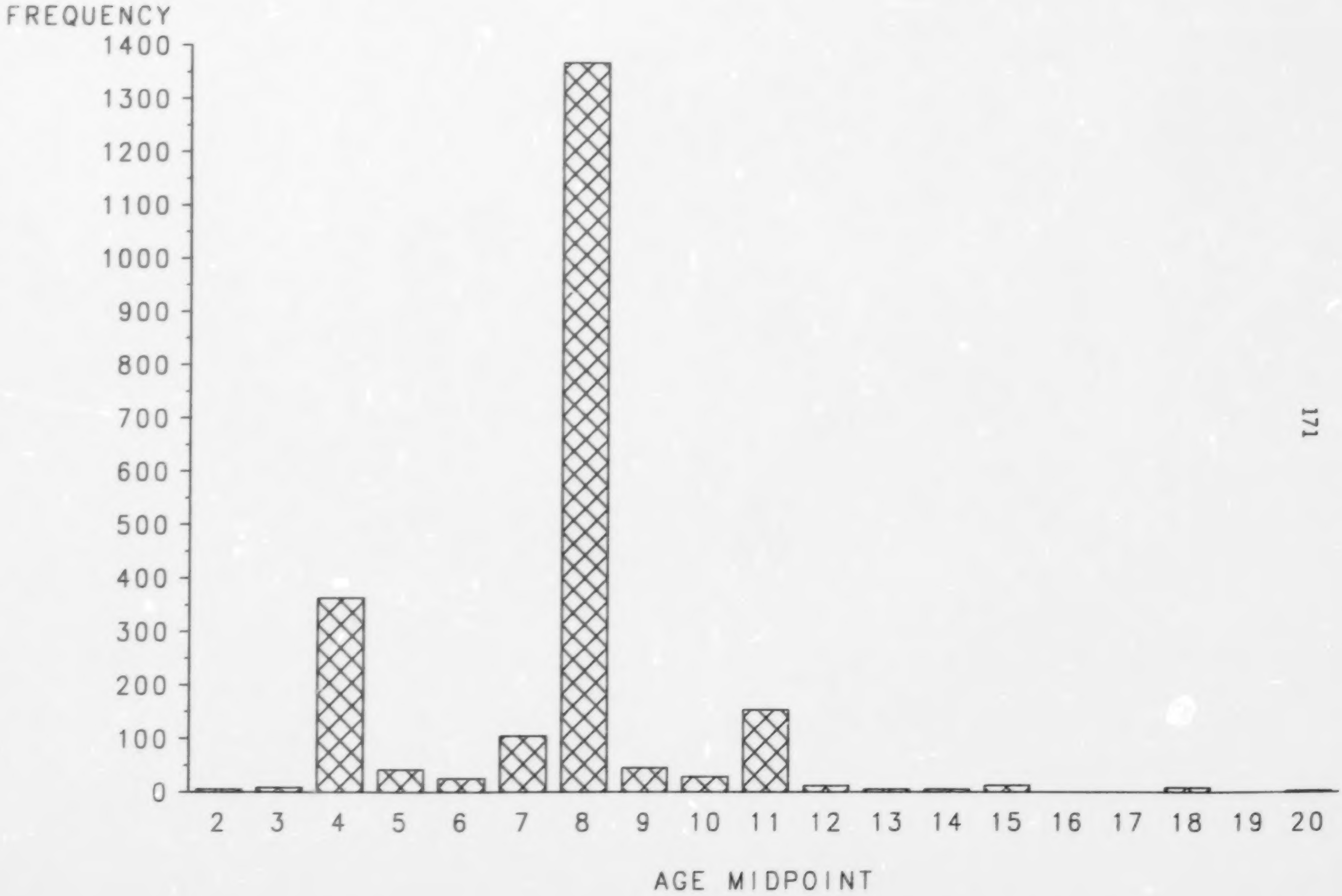
Note: Strong recruitment = 3.178 billion (mean of top 25 percent historical recruitments)
Weak recruitment = 0.137 billion (mean of historical recruitments below median)

Table 6.9. Summary of the 1990-1992 potential yields. Yield and biomass projections are in thousands of tons. Recruitment scenarios are described in Table 19 (from Dorn and Methot 1989).

Variable effort, low risk strategy (F = 0.21)					Constant effort, low risk strategy (F = 0.18)				
	Year	Yield	Spawn. Biomass	Age 2+ Biomass		Year	Yield	Spawn. Biomass	Age 2+ Biomass
	1990	126	599	1998		1990	137	599	1998
Recr. scenario A:	1991	129	711	1887	Recr. scenario A:	1991	118	706	1876
	1992	171	731	1678		1992	154	731	1680
	1990	114	599	1189		1990	123	599	1189
Recr. scenario B:	1991	76	481	1776	Recr. scenario B:	1991	101	476	1767
	1992	106	638	1748		1992	105	622	1716
	1990	114	599	1189		1990	123	599	1189
Recr. scenario C:	1991	67	481	967	Recr. scenario C:	1991	88	476	958
	1992	58	407	1634		1992	88	392	1606
	1990	114	599	1189		1990	123	599	1189
Recr. scenario D:	1991	67	481	967	Recr. scenario D:	1991	88	476	958
	1992	50	407	825		1992	75	392	797

Variable effort, moderate risk strategy (F = 0.35)					Constant effort, low risk strategy (F = 0.18)				
	Year	Yield	Spawn. Biomass	Age 2+ Biomass		Year	Yield	Spawn. Biomass	Age 2+ Biomass
	1990	200	599	1998		1990	198	599	1998
Recr. scenario A:	1991	184	676	1815	Recr. scenario A:	1991	163	677	1817
	1992	228	673	1661		1992	207	683	1583
	1990	180	599	1189		1990	179	599	1189
Recr. scenario B:	1991	106	448	1713	Recr. scenario B:	1991	138	449	1714
	1992	144	595	1663		1992	139	581	1633
	1990	180	599	1189		1990	179	599	1189
Recr. scenario C:	1991	92	449	904	Recr. scenario C:	1991	118	449	905
	1992	76	365	1555		1992	114	352	1531
	1990	180	599	1189		1990	179	599	1189
Recr. scenario D:	1991	92	449	904	Recr. scenario D:	1991	118	449	905
	1992	63	365	746		1992	94	352	722

Fig. 6.1. Age frequency of offshore Pacific hake in Canadian waters during 1988.


FREQUENCY
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
2
3
4
5
6
7
8
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11
12
13
14
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16
17
18
19
20
AGE MIDPOINT

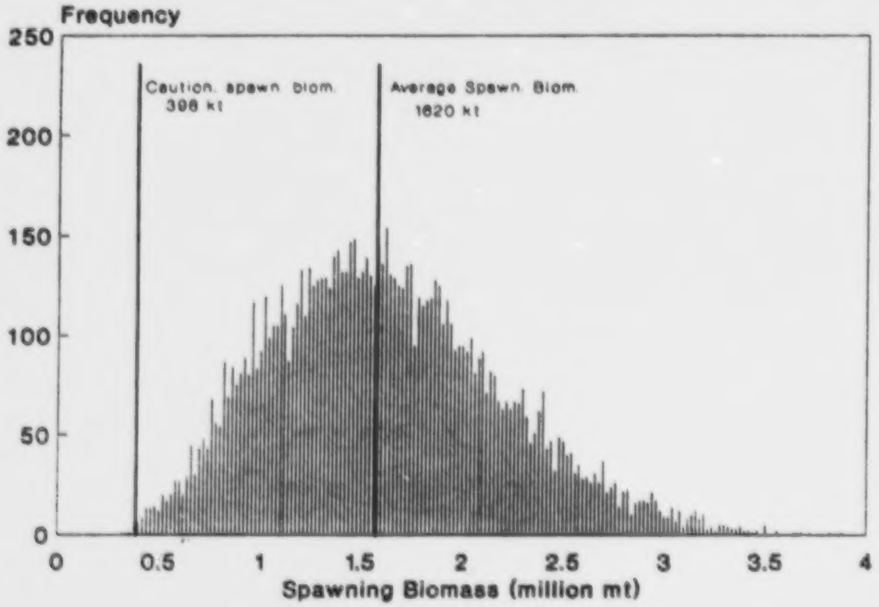


Fig. 6.2. Frequency histogram of spawning biomass (million mt) resulting from ten replicate 1000 year simulations of an unexploited hake population. Recruitments to drive the model were obtained by resampling from the observed recruitments 1959-1986. A cautionary level of spawning biomass of 398 kt was identified as the 0.1 percentile of the empirical distribution of spawning biomass for an unexploited population (from Dorn and Methot 1989).

7.0 DOGFISH

by M. W. Saunders

7.1. Coastwide (not including Strait of Georgia)

7.1.1. Introduction

The offshore stock referred to in this assessment ranges from Alaska to California and does not include the Strait of Georgia-Puget Sound stock(s).

7.1.2. Landing Statistics

The offshore catch increased to 3897 t in 1988 from 2996 t in 1987. The bulk of offshore nominal catch of dogfish in 1988 came from Major Area 3C (85.0%) with the catch evenly split between longline (43.6%) and trawl fisheries (Table 7.1).

The trawl and longline fisheries are conducted during the first and second quarters (Table 7.2) when the large, primarily female fish (> 80 cm), that processors demand are available to the fleet.

Offshore Washington State trawl landings remained low (133 t) in 1988 (Table 7.3). Longline catches were not available for this assessment.

Dogfish remain unexploited off Oregon and California.

7.1.3. Condition of Stock

There have been no new analyses conducted since the previous assessment (Saunders 1989). At current harvest levels of less then 2500 t, the marketable biomass of dogfish is predicted to continue increasing over the next decade. The estimated biomass coastwide at the present time is approximately 280,000 t. Assuming that one-half to two-thirds of the stock resides off the coast of Canada, the biomass of fish in the Canadian zone is between 150,000-200,000 t.

7.1.4. Yield Options

Possible options include sustained yield, pulse fishing and a variable catch no-nuisance strategy.

A sustained yield fishery will produce oscillations in abundance but they will decrease in amplitude with time. Hence this strategy provides a steady supply while maintaining a stock size lower than present levels. For removals from the offshore stock, including Alaska, British Columbia, Washington, Oregon, and California waters, up to 15,000 t may be considered low risk sustainable and 25,000 t high risk sustainable assuming an equal sex ratio. If a first and second quarter fishery is to be sustained then yields up to 9,000 t are low risk while 15,000 t yields are high risk. Yields are lower with a first and second quarter fishery because the fishery targets almost exclusively large females which reduces the reproductive potential of the stock and lowers estimates of yield.

The range in levels presented is a reflection of the uncertainty surrounding estimates of starting stock size and the degree of compensatory mortality used in forward simulations. At risk is the collapse of the spawning stock.

Industry has expressed concern over the high abundance of dogfish, which is viewed as a nuisance, and has asked if it is possible to maintain the population at below nuisance levels while continuing to support a directed domestic fishery.

One of the control options proposed is periodic or pulse fishing which is the removal of large quantities of fish at a specific time interval. Figure 7.1 (Saunders 1986, p. 48) illustrates the effect over time of removing a substantial catch in a single year. The biomass of marketable stock is capable of rebuilding to present levels within 3-4 years of removing 30,000 t and within 10 years of removing an unattainable figure of 210,000 t.

The large removal, as discussed in Saunders (1985), accentuates and perpetuates the pulse in abundance introduced by the 1940's liver fishery. The extreme variation in abundance resulting from a pulse fishery is further illustrated by Figure 7.2 (Saunders 1986, p. 49), a forward simulation of marketable biomass with catches of 60,000 t taken every fifth year. While 60,000 t removals keep the population below the present level for 10 years, over the ensuing 25 years the stock fluctuates to well above present levels and to well below a level where commercial fishing is likely to be viable. The point when fishing is assumed to be non-viable is at, or below, the level of the predicted biomass in 1950, at the end of the liver fishery when, as a result of heavy fishing pressure, the abundance decreased to a level where fishing success was poor.

An alternative approach, entitled variable catch/no nuisance option, is to fish intensively for several years until the stock is below nuisance levels and then regulate catch to remove more fish in years when recruitment is high from the liver fishery pulse and vice versa when recruitment is decreasing. Figure 7.3 (Saunders 1986, p. 50) shows the effect of such a strategy on marketable biomass over time. Initial catches of 30,000 t for the first four years lower the stock rapidly and catches thereafter ranging from 8,000 to 25,000 t per year maintain a relatively stable stock size.

At current catch rates the trawl effort required to catch the maximum tonnages involved is equivalent to the effort expended in a year by the entire groundfish trawl fleet on all species. One possible way to obtain sufficient effort is to establish a joint venture fishery to remove the difference of the yearly catch that domestic markets cannot utilize.

All options refer to coastwide (including U.S.) removals and no provision has been made for adjusting Canadian catches in the event of increased U.S. catch.

Yield option 1: Sustained yield, no 1st and 2nd quarter fishery

- low risk - 15,000 t
- high risk - 25,000 t

Yield option 2: Sustained yield - first and second quarter fishery, only.

- low risk - 9,000 t
- high risk - 15,000 t

Yield option 3: Pulse fishing

The impact of specific pulse fisheries proposed by management can be assessed when proposed. For example a fishery of 60,000 t taken every five years can be sustained.

Yield option 4: Variable catch/no nuisance

This option maintains stock biomass below a nuisance level. Catches of 30,000 t for 4 years to reduce the stock to below the nuisance level and catches of 8,000-25,000 t beyond the first 4 years.

7.2 Strait of Georgia - Puget Sound

7.2.1 Introduction

This assessment treats the Strait of Georgia and Puget Sound as a single stock. The 1988 assessment remains unchanged from the last major assessment (Saunders 1988).

7.2.2. Landing Statistics

Longline catches were up to 804 t in 1988 from 788 t caught in 1987. Trawl catches decreased from 357 t in 1987 to 201 t in 1988 (Table 7.2). The landings for 1988 by minor statistical area, quarter and gear type are presented in Table 7.4.

7.2.3. Condition of the Stock

At current harvest levels (approx. 1000 t) abundance should continue to increase over the next few years. Current biomass levels are in the order of 60,000 t. The trends in inshore abundance discussed can be viewed only qualitatively until questions regarding the degree of mixing between Puget Sound, offshore and Strait of Georgia stocks, and the impact of sports and bait fisheries, have been answered, and until an estimate of absolute abundance is obtained for accurate calibration of model projections.

7.2.4. Yield Options

Dogfish may be harvested on a sustained or periodic fishery basis.

Over the long term, removals from the Strait of Georgia-Puget Sound stock that are in the range of 4000 to 6000 t may be considered low-risk sustainable, while removals in excess of 6000 t are considered high-risk sustainable. Assuming an even split in biomass between the Strait of Georgia and Puget Sound, 2000 t is considered low-risk and 3000 t is considered high-risk for the Strait of Georgia. Again this range is a reflection of the uncertainty surrounding estimates of starting stock size and the degree of compensatory mortality used in forward simulations.

Yield option 1: Sustained yield - low-risk - 2000 t

Yield option 2: Sustained yield - high-risk - 3000 t

Table 7.1. Dogfish longline and trawl catch[a] (t) offshore, by Major Area and by gear for 1979-1988.

	3C				3D			5A			5B		
	LL[b]	Tr[c]	HL&T[d]	Tot.	LL	Tr	Tot.	LL	Tr	Tot.	LL	Tr	Tot
1979	4	279	-	283	1	15	16	5	10	15	-	5	5
1980	7	1732	-	1739	26	116	142	5	117	122	-	39	39
1981	10	285	-	295	-	17	17	-	25	25	-	-	0
1982	-	947	-	947	3	23	26	11	14	25	-	45	45
1983	92	450	-	542	-	54	54	16	-	16	-	9	9
1984	-	455	-	455	-	3	3	54	45	99	-	9	9
1985	-	1365	-	1365	60	74	134	360	52	412	38	2	40
1986	73	1770	-	1843	26	65	91	73	105	178	-	-	0
1987	1075	1064	3	2142	141	40	181	298	44	342	8	20	28
1988	1848	1442	21	3311	150	36	186	144	47	191	93	-	93

	5C				5D			5E				Total			
	LL	Tr	HL&T	Tot	LL	Tr	Tot	LL	Tr	HL&T	Tot	LL	Tr	HL&T	Tot.
1979	1	11	-	12	26	70	96	-	-	-	-	37	390	-	427
1980	13	59	-	72	91	242	333	-	1	-	1	142	2306	-	2448
1981	-	9	-	9	10	32	42	-	-	-	-	20	368	-	388
1982	3	-	-	3	-	272	272	-	-	-	-	17	1301	-	1318
1983	-	3	-	3	-	17	17	-	-	-	-	108	533	-	641
1984	-	15	-	15	-	73	73	-	-	-	-	54	600	-	654
1985	-	-	-	-	4	4	8	-	-	-	-	462	1497	-	1959
1986	-	1	-	1	11	9	20	-	-	-	-	183	1950	-	2133
1987	241	1	.3	242	61	3	64	-	-	-	-	1823	1173	3.3	2996
1988	47	2	-	49	25	-	25	41	-	2	43	2347	1527	23	3897

[a] Interview and sales slip data from Smith 1980, 1981, Leaman 1982, 1983 and Department of Fisheries and Oceans catch statistics data base.

[b] LL = longline.

[c] Tr = trawl.

[d] HL&T = handline and troll.

Table 7.2. Dogfish landings[a] (t) for Major Areas 4B and 3C, by gear and quarter for 1979 to 1988.

	Area 4B											
	Longline					Trawl					HL&T	
	Quarter					Quarter						
	I	II	III	IV	Total	I	II	III	IV	Total	Total	Grand Total
1979	747	206	419	2081	3453	9	7	106	669	791	-	4244
1980	806	482	23	229	1540	288	34	-	242	564	-	2104
1981	5	2	-	486	493	88	-	-	182	270	-	763
1982	302	67	6	464	839	100	28	120	171	419	-	1258
1983	273	128	55	336	792	81	111	70	173	435	-	1227
1984	353	260	347	635	1595	26	80	112	78	296	-	1891
1985	278	112	5	44	439	166	180	9	77	432	-	871
1986	70	17	0	0	87	114	116	16	147	393	-	480
1987	233	49	37	469	788	58	110	79	110	357	-	1145
1988	582	159	4	60	804	64	66	39	32	201	2	1007

Table 7.2 (cont'd)

	Area 3C											
	Longline					Trawl					HL&T	
	Quarter					Quarter						
	I	II	III	IV	Total	I	II	III	IV	Total	II	Grand Total
1979	3	-	-	1	4	2	200	49	28	279	-	283
1980	2	5	-	-	7	512	1111	109	-	1732	-	1739
1981	-	-	-	9	9	37	208	17	24	286	-	295
1982	-	-	-	-	-	209	612	82	44	947	-	947
1983	-	83	9	-	92	180	147	50	73	450	-	542
1984	-	-	-	-	-	239	127	67	22	455	-	455
1985	-	-	-	-	-	450	788	42	85	1365	-	1365
1986	56	17	-	-	73	729	883	13	146	1771	-	1844
1987	186	559	78	251	1074	535	483	0.3	46	1064	-	2138
1988	79	1032	2	22	1848	249	1192	0.4	-	1442	21	3311

[a] Includes sales slip information.

Table 7.3. Dogfish landings[a] (t) by gear from Washington State.

	Trawl	Longline	Other	Total
1983				
Inshore[b]	856	435	-	1291
Offshore[c]	21	5	-	26
1984				
Inshore	753	504	188	1445
Offshore	239	79	-	318
1985				
Inshore	469	363	139	971
Offshore	172	101	1	274
1986				
Inshore	304	325	117	746
Offshore	83	29	1	113
1987				
Inshore	373	721	335	1429
Offshore	91	893	-	984
1988				
Inshore	371	-[d]	-	374
Offshore	133	-[d]	-	984

[a] From Technical Sub-committee, Washington State Status Reports, unpublished text.

[b] Major Area 4A.

[c] All Major Areas excluding 4A.

[d] Longline landings unavailable.

Table 7.4. Dogfish landings (kg) for Minor statistical areas in the Strait of Georgia during 1988 by quarter and gear (Trawl=mid-water and bottom trawl combined; Hl and T= handline and troll).

	Minor 12					Minor 13				
	Q1	Q2	Q3	Q4	Total	Q1	Q2	Q3	Q4	Total
Longline	188	6369	-	-	6557	34751	13556	-	-	48307
Trawl	-	-	-	-	-	-	-	-	-	-
Hl and T	-	-	249	227	476	-	-	-	-	-
Total	188	6369	249	227	7033	34751	13556	-	-	48307

	Minor 14					Minor 15				
	Q1	Q2	Q3	Q4	Total	Q1	Q2	Q3	Q4	Total
Longline	34987	16642	-	11693	63322	13314	15596	-	-	28910
Trawl	-	27115	25276	-	52391	-	-	-	-	-
Hl and T	-	-	-	-	-	525	-	-	-	525
Total	34987	43757	25276	11693	115713	13839	15596	-	-	29435

Table 7.4. (cont'd)

	Minor 16					Minor 17				
	Q1	Q2	Q3	Q4	Total	Q1	Q2	Q3	Q4	Total
Longline	40898	3582	-	-	44480	170417	19856	-	34344	224617
Trawl	-	-	-	-	-	-	-	-	419	419
Hl and T	-	-	-	-	-	355	282	-	-	637
Total	40898	3582	-	-	44480	170772	20138	-	34763	225673

	Minor 18					Minor 19				
	Q1	Q2	Q3	Q4	Total	Q1	Q2	Q3	Q4	Total
Longline	73994	11039	-	2066	87099	6367	-	-	-	6367
Trawl	6499	8412	13329	14833	43073	36724	-	-	15289	52013
Hl and T	-	-	-	-	-	-	3	41	5	49
Total	80493	19451	13329	16899	130172	43091	3	41	15294	58429

Table 7.4. (cont'd)

	Minor 20					Minor 29				
	Q1	Q2	Q3	Q4	Total	Q1	Q2	Q3	Q4	Total
Longline	153659	17329	-	-	170988	53335	54595	4184	11534	123648
Trawl	-	-	-	-	-	21095	30905	-	1090	53090
Hl and T	-	-	-	-	-	-	-	-	-	-
Total	153659	17329	-	-	170988	74430	85500	4184	12624	176738

8.0 WALLEYE POLLOCK

8.1. Coastwide

Yield options are not proposed on a coastwide basis.

8.2. Strait of Georgia

8.2.1. Introduction

Walleye pollock are an abundant resident fish cohabiting with Pacific hake in the Strait of Georgia. The fishery has been decreasing over the past years as a result of poor market conditions. All of the pollock catch is processed into frozen fillets which are used as a substitute for Pacific cod fillets.

The 1988 assessment remains unchanged from the previous assessment (Shaw et al. 1985).

8.2.2. Landing Statistics

During 1988, a total of 665 t was landed, a decrease of 46.2% from the 1987 landings (Table 8.1). The landings were predominantly (99.1%) from trawlers using midwater gear (Table 8.2). The majority (94.6%) of the landings were in the first quarter. This year's decrease reflects poor market conditions.

8.2.3. Condition of Stock

The previous assessment was based on estimates of maximum sustainable yield (MSY) using Gulland's (1970) relationship of $MSY = a(M)(B)$. The following parameter estimates used in the equation were: natural mortality (M) of 0.5-0.7; value of (a) of 0.3-0.5; and a biomass (B) estimate of 15,800-29,400 t (Shaw et al. 1985). The previously calculated yield levels are still appropriate in light of hydroacoustic and swept-volume trawl surveys conducted in 1988 which indicate that the biomass still falls within the above range (Shaw et al. 1989).

8.2.4. Yield Options

The conservative level is based on the lower level of unexploited biomass (15,800 t), a natural mortality of $M=0.5$, and a constant (a) value of 0.3. The high risk level is based on a midpoint of the biomass estimate (22,600 t), a midpoint in the natural mortality estimate $M=0.6$ and a constant value of $a=0.4$, which Gulland (1983) indicated as a realistic value for gadid-like species.

Yield options may be chosen from:

Yield option 1: Conservative sustainable - 2500 t

Yield option 2: Risk sustainable - 5400 t

8.3. West Coast Vancouver Island

8.3.1. Introduction

Walleye pollock remain a small incidental catch in the joint venture Pacific hake fishery off the west coast of Vancouver Island (Major Area 3C). Small quantities of pollock are caught incidentally by the domestic fleet while targeting on other groundfish species in Major Areas 3C and 3D.

8.3.2. Landing Statistics

The landings by foreign fleet in 1988 decreased from 1168 t in 1987 to 228 t (Table 8.3). The majority (99%) of these landings were from the joint venture fishery.

The domestic fleet reported a catch of 3 t of pollock from Major Area 3C (Table 8.1).

8.3.3 Condition of Stock.

There has been no new analysis conducted for the 1989 assessment.

8.3.4. Yield Options

The yield options remain unchanged from the previous assessment (Shaw et al. 1985).

Yield option 1 : unrestricted yield.

8.4 Queen Charlotte Sound

Yield options are not proposed for this region.

8.5. Hecate Strait

8.5.1. Introduction

The walleye pollock fishery in northern Hecate Strait and Dixon Entrance (Major Areas 5C and 5D), occurs mainly in the winter months, from November to December, when fish are processed into fillets and act as a substitute for Pacific cod. There is no demand for pollock fillets or roe and the markets have not improved since the late 1970s.

The 1988 assessment remains unchanged from the previous assessment (Shaw et al. 1985).

8.5.2. Landing Statistics

Pollock landings in 1988 increased to 52 t from 4 t reported for 1987 (Table 8.4). There were 3 t landed from Major Area 5C and 49 t was caught in Major Area 5D.

8.5.3 Condition of Stock

The status of this stock is currently unknown since there has been neither an active fishery nor research cruises conducted since the late 1970s. Recent review of evidence for stock delineation of pollock in Canadian waters (Saunders et al. 1989) suggests that the stock ranges throughout southeast Alaska, Dixon Entrance and Hecate Strait. Should industry interest grow, the stock should be re-assessed and until that time yield remains unrestricted.

8.5.4. Yield Options

The yield options remain unchanged from the previous assessment (Shaw et al. 1985). The catch is currently limited due to weak markets.

Yield option 1: Unrestricted yield.

8.6.1 West Coast of Queen Charlotte Islands

Yield options are not proposed for this region.

Table 8.1. Total landings (t) of walleye pollock by the domestic fleet by major statistical area, 1954-88.

Year	Landings (t)									
	4B	3B	3C[a]	3D	5A	5B	5C	5D	5E	Total
1954	147	0	3	0	13	1	0	0	0	164
1955	418	0	5	0	1	0	0	3	0	427
1956	380	0	52	0	5	0	0	14	0	451
1957	248	0	4	0	3	0	0	7	0	262
1958	121	0	0	0	.3	0	0	14	0	135
1959	260	0	8	0	.4	0	0	2	0	270
1960	95	0	5	0	1	3	0	10	0	114
1961	115	0	.1	0	1	0	.3	7	0	123
1962	49	0	6	0	0	0	0	12	0	67
1963	13	0	7	0	6	0	0	4	0	30
1964	33	0	2	0	5	0	0	2	0	42
1965	26	0	10	0	0	0	0	9	0	45
1966	37	0	.4	0	1	.1	.4	82	0	121
1967	33	0	0	0	1	0	7	48	0	89
1968	16	0	2	0	7	0	4	13	0	42
1969	30	0	14	0	33	0	0	47	0	124
1970	45	0	0	0	0	0	0	8	0	53
1971	80	0	5	0	0	0	0	0	0	85
1972	71	0	.3	0	172	0	0	1	0	244
1973	9	0	.1	0	62	9	.4	13	0	94
1974	11	0	0	0	6	6	2	47	0	72
1975	1	0	0	0	21	10	1	70	0	103
1976	26	0	5	2	69	400	193	627	.2	1322
1977	50	0	10	0	61	175	16	567	12	891
1978	380	0	6	.4	106	187	11	1700	21	2411
1979	1341	0	31	.3	72	71	238	1566	67	3386
1980	1056	0	3	3	12	23	83	1103	18	2301
1981	570	0	8	1	2	10	79	563	22	1255
1982	100	0	10	0	1	6	3	808	1	929
1983	25	0	3	1	11	10	6	986	28	1070
1984	157	0	5	0	11	7	2	625	< .1	807
1985	748	0	4	0	0	1	0	1176	2	1931
1986	469	0	3	0	0	0	0	95	0	567
1987	1237	0	0	0	29	5	0	4	0	1275
1988	665	0	3	0	2	2	0	4	0	681

[a] Excludes incidental landings by the foreign fleet participating in the offshore Pacific hake fishery during 1980 to 1988.

Table 8.2. Walleye pollock landings by gear type and by quarter from the Strait of Georgia (Major Area 4B), 1976-1988.

		Major Area 4B		
Year		Quarter 1	Quarter 4	Total
1976				
	MWT [a]	-	-	0
	BT [b]	3	23	26
	Total	3	23	26
1977				
	MWT	-	-	0
	BT	24	26	50
	Total	24	26	50
1978				
	MWT	177	-	177
	BT	142	41	183
	Total	319	41	360
1979				
	MWT	1033	3	1036
	BT	283	20	303
	Total	1316	23	1339
1980				
	MWT	841	-	841
	BT	189	23	212
	Total	1030	23	1053
1981				
	MWT	455	-	455
	BT	99	5	104
	Total	554	5	559
1982				
	MWT	81	-	81
	BT	8	7	15
	Total	89	7	96
1983				
	MWT	19	-	19
	BT	3	2	5
	Total	22	2	24
1984				
	MWT	8	90	98
	BT	-	2	2
	Total	8	92	100
1985				
	MWT	401	319	720
	BT	5	19	24
	Total	406	338	744

Table 8.2. (cont'd)

Year		Major Area 4B		
		Quarter 1	Quarter 4	Total
1986				
	MWT	162	294	456
	BT	10	2	12
	Total	172	296	468
1987				
	MWT	1118	56	1174
	BT	3	15	18
	Total	1121	71	1192
1988				
	MWT	631	29	661
	BT	3	4	11
	Total	634	33	667

[a]MWT = Midwater trawl.
[b]BT = Bottom trawl.

Table 8.3. Incidental catches of walleye pollock by foreign fleets participating in the offshore hake fishery off west coast Vancouver Island (Major Area 3C), 1980-1988. (Catch statistics from Offshore Division, Vancouver.)

		Landings (t)		
Year	Nations	National[a]	Joint venture	Total
1980	Poland	487	236	
	USSR	63	584	
	Japan	142	0	
	Greece	-	175	
	Total	692	995	1687
1981	Poland	131	205	
	USSR	26	299	
	Japan	9	0	
	Greece	-	285	
	Total	166	789	955
1982	Poland	468	222	
	USSR	0	149	
	Japan	38	-	
	Total	506	371	877
1983	Poland	13	6	
	USSR	-	-	
	Total	13	6	19
1984	Poland	1	66	
	USSR	-	41	
	Total	1	107	108

Table 8.3. (cont'd)

		Landings (t)		
Year	Nations	National[a]	Joint venture	Total
1985	Poland	2	78	
	Total	2	78	80
1986	Poland	14	19	
	USSR	1	63	
	Total	15	82	97
1987	Poland	22	686	
	USSR	64	325	
	Korea	-	71	
	Total	86	1082	1168
1988	Poland	1	177	
	USSR	0	50	
	Japan	0	0	
	Total	1	227	228

[a] "National" landings include landings from the supplementary fishery.

Table 8.4. Walleye pollock landings by gear type and by quarter from Major Areas 5C and 5D, 1976-1988.

Year		Major Area 5C				Major Area 5D			
		Quarter1	Quarters2,3	Quarter4	Total	Quarter1	Quarter2,3	Quarter4	Total
1976	MWT[a]	-	25	102	127	-	208	56	264
	BT[b]	<1	19	47	66	5	141	214	360
	Total	<1	44	149	193	5	349	270	624
1977	MWT	-	-	-	0	<1	<1	-	<1
	BT	1	14	1	16	34	509	24	567
	Total	1	14	1	16	34	509	24	567
1978	MWT	-	1	-	1	425	299	71	795
	BT	1	7	2	10	107	657	141	905
	Total	1	8	2	11	532	956	212	1700
1979	MWT	-	-	-	0	593	52	11	656
	BT	1	103	134	238	119	521	270	910
	Total	1	103	134	238	712	573	281	1566
1980	MWT	-	<1	-	<1	201	261	9	471
	BT	1	73	9	83	116	482	34	632
	Total	1	73	9	83	317	743	43	1103
1981	MWT	-	-	-	0	61	-	79	140
	BT	27	21	31	79	71	248	104	423
	Total	27	21	31	79	132	248	183	563
1982	MWT	-	-	-	0	2	-	607	609
	BT	<1	3	<1	3	4	98	97	199
	Total	<1	3	<1	3	6	98	704	808
1983	MWT	-	-	-	0	-	34	784	818
	BT	-	6	-	6	43	46	79	168
	Total	0	6	0	6	43	80	863	986
1984	MWT	-	-	-	0	301	-	266	567
	BT	-	2	-	2	13	40	5	58
	Total	0	2	0	2	314	40	271	625

Table 8.4. (cont'd)

Year		Major Area 5C				Major Area 5D			
		Quarter1	Quarters2,3	Quarter4	Total	Quarter1	Quarter2,3	Quarter4	Total
1985	MWT	-	-	-	0	369	0	754	1123
	BT	-	-	-	0	10	42	1	53
	Total	0	0	0	0	379	42	755	1176
1986	MWT	-	-	-	0	66	0	2	68
	BT	-	-	-	0	8	18	1	27
	Total	0	0	0	0	74	18	3	95
1987	MWT	-	-	-	0	1	1	-	2
	BT	-	-	-	0	-	2	-	2
	Total	0	0	0	0	1	3	0	4
1988	MWT	0	0	0	0	0	0	0	0
	BT	0	3	0	3	18	23	8	49
	Total	0	3	0	3	18	23	8	49

[a] MWT = Midwater trawl.
[b] BT = Bottom trawl.

9.0 SLOPE ROCKFISHES (Sebastes alutus, S. reedi, S. aleutianus, and S. proriger)

by B. M. Leaman

9.0.1 General Introduction

Rockfishes are the mainstay of the B.C. trawl fishery and landings of slope rockfishes increased steadily between 1979-1986 (Fig. 9.1). Coastwide landings have declined slightly in recent years but remain an important component of the fishery. The central element which continues to affect the quality of both rockfish stock assessment and management is the reliability of the underlying catch and effort statistics. Historical statistics were based on voluntary logbook records. However, the percentage of the fleet providing such records began to decrease as fleet effort expanded, disagreements with Departmental policies intensified, and quotas were rapidly subscribed. The introduction of mandatory logbook and hail systems in 1988 has not provided significant improvement, due to the difficulty of enforcing these measures. The vast area of the offshore fishing grounds, increasing number of participants, large economic incentives to falsify species' catches and areas, increasing use of isolated ports of landing, and limited surveillance resources (relative to needs) all contribute to this failure. Reports of data falsification are common, unsolicited, and appear to be confirmed by the limited circumstantial evidence which is available.

An additional feature affecting stock assessment is the comparability of statistical (and to some degree, biological) data collected in previous years, with those collected under the present management plan. Availability of aggregated species is affected by the absolute magnitude of fishing pressure. In previous years, most rockfish fisheries operated almost continuously throughout the year, but now operate in the same way for only a few weeks out of each quarter. Fishing pressure breaks up aggregations and decreases catch rate (CPUE). CPUE becomes less meaningful as trip limits become smaller; the general effect being an inflation of the CPUE index as trip limits are attained before fishing effort produces its normal effect on CPUE. Sampling opportunities also diminish as small catches from many different limit-areas are mixed in vessel holds. Seasonal availability patterns of both species and sexes within species also create data problems if commercial landings are the sole source of samples. Low trip limits in effect for most of the year may restrict sampling opportunities to inappropriate time periods. We noted these problems in the previous assessment (Leaman 1989); they have persisted and increased during 1989.

Achievement of management goals for rockfishes in recent years has, in general, been poor. Catches are rarely kept within quota limits for both individual stocks and coastwide aggregates (Figs. 9.2 - 9.5). Imprecision and long reaction times to changes in the fishery by management have played key roles in this result. However, management is made more difficult by the complex structure of rockfish stock units, their variable levels of exploitation history, and consequent differences in their current productivity. The relatively high degree of aggregation among species also creates problems for both fishermen and enforcement personnel in the successful management of quotas for some areas. Rapid subscription of small quotas for some species can result in by-catch problems for other species.

For 1989, managers implemented coastwide trip limits in an attempt to reduce the complexity of the previous management plan. This measure, similar to that used in 1986, treats the coast as if it contained only a single stock of each species. The result, to date, is that catches are not taken from individual stocks on the basis of their productivity, but on the basis of their proximity to ports. The stocks with largest quotas are farthest from ports, hence those nearest to ports are being overexploited. If this process continues, it will decrease both the yield from these stocks and coastwide yields.

The 1976 cohort of Pacific ocean perch (Sebastes alutus) continues to recruit as a relatively strong cohort to most stocks. We estimate it to be approximately 60% of the strength of the 1952 cohort, which may have been the strongest of the century. However, it also appears that, while the 1976 cohort is relatively strong in all stocks, it is much stronger in absolute numbers in those stocks where there is a relatively large adult biomass (Moresby Gully, south Queen Charlotte Islands). This suggests that, while conditions for strong recruitment may be wide-scale coastal phenomena, local spawning abundance may affect absolute abundance of a cohort. If allowed to contribute maximally, this cohort may provide significant rehabilitative potential for depleted stocks. However, this will require that it receive low fishing mortality for a substantial portion of its residency in fishable stocks. If it does not receive low fishing mortality, it will contribute little to the rehabilitation of these stocks. The reader is directed to Section 9.8.1 for a presentation of such a fate for this cohort in the unrestricted Langara fishery. Clearly, even relatively low fishing effort is sufficient to deplete this cohort when it constitutes the majority of the fishable stock.

As in the previous assessment, sustainable yield options are presented as a range of values (Table 9.1). This range varies in width depending on our relative level of confidence in the data upon which the assessments are based. The lower value in the range represents a sustainable yield level with a low risk of stock decline, while the upper value represents a relatively high risk of stock decline. In other words, this range is an increasing scale of probability that a stock will decline with that yield; it is not a confidence interval. In some instances this probability has been quantified (Archibald et al. 1983; Fig. 6). Additionally, the conservative and non-sustainable options are presented as limits (e.g., greater than or less than xxx t), rather than as specific values. While we have in past presented single values for yield options, there is imprecision in both observations and techniques and a range of values more accurately reflects the precision of our understanding. The conceptual basis for these figures remains as outlined in previous documents (Leaman and Stanley 1985, Leaman 1988).

9.3.1 Southwest Vancouver Island Pacific ocean perch (Sebastes alutus) (including Management Area 125)

9.3.1.1 Introduction

There have been no new analytic studies of this stock. The quota was returned to the estimated sustainable level (150t) in 1987 after a 4-y overharvesting experiment. Since that time an attempt has been made to restrict the harvest to incidental landings only. For 1989, this took the form of a 4.5 t trip limit from 01/01/89 to 31/03/89 and a 2 t trip limit thereafter. However, it is apparent that vessels continue to target on these small limits, and landings since 1987 have continued at or above the level reached during the experimental overharvest. They have also been well in excess of the quota (Fig. 9.6).

9.3.1.2 Landing Statistics

Nominal statistics of the fishery are variable but have generally declined since the fishery was re-opened in 1980 (Fig. 9.7). While statistics of the 1987-1989 fishery are less meaningful due to the restriction to an incidental fishery, CPUE continues to decline. Qualified effort remains at a surprisingly high level, indicating this fishery is conducted as a target fishery in spite of the low trip limit (Table 9.2).

9.3.1.3 Condition of the Stock

The 3C S. alutus stock remains in poor condition. During the period of experimental fishing qualified catch rates declined over 50% from those of the 1979 survey (Lapi and Richards 1981). The 1985 U.S. and Canadian biomass surveys showed declines of 63% and 56% in the estimated size of the S. alutus stock, respectively. Those areas receiving the greatest fishing effort since 1979 (Estevan, Clayoquot, Cape Flattery) showed the greatest relative declines in biomass (Leaman et al., 1988). Limited biological data are available from recent years due to the difficulty in obtaining samples from an incidental fishery. However, catch data do not indicate any improvement in stock condition.

Optimal long-term stock size is in the range of 25,000-32,000 t, depending on the estimates of virgin stock size and the productivity relationship of the species used. For example, Ito et al. (1987) calculated maximum productivity at ~0.33 of the virgin biomass but cautioned that the productivity-stock size relationship employed was extremely uncertain. Alternatively, Archibald et al. (1983) calculated maximum productivity at ~0.47 times the virgin biomass, on the basis of a detailed biological model.

9.3.1.4 Yield Options

The S. alutus stock off southwest Vancouver Island remains in poor condition. Equilibrium yield estimates (~70-200 t) remain as calculated in the 1989 assessment (Table 9.1). Rehabilitation of this stock to its most productive level should not be expected within the next decade, even with very low fishing mortality, although this process would be enhanced if the 1976 cohort were allowed to contribute maximally to stock biomass and reproduction.

9.3.2. Southwest Vancouver Island redstripe rockfish (Sebastes proriger)

9.3.2.1 Landing Statistics

Historical landings of S. proriger off southwest Vancouver Is. have been extremely limited (Table 9.3). However, in 1986 the adoption of coastwide slope rockfish quotas, and rapid subscription thereof, forced the domestic fleet to search for other red rockfish to satisfy strong market demands. Although considerably smaller than S. alutus in most areas, S. proriger do attain marketable size (>30 cm) off southwest Vancouver Is. and their landings underwent a dramatic increase in 1986, particularly after the existing slope rockfish quotas were filled. Landings declined after 1986 and have remained relatively stable. While landings in 1989 are above the comparable period of 1988, both nominal and qualified CPUE are substantially lower after a period of stability (Fig. 9.8). No management has ever been applied to this stock.

9.3.2.2 Condition of the Stock

No quantitative conclusions concerning the condition of this stock are presently possible. There are no biological samples and the fishery results are of limited usefulness.

9.3.2.3 Yield Options

The sustainable yield (Table 9.1) for *S. proriger* in Area 3C is estimated to range from 200-1000 t (Leaman 1988). In the absence of detailed analysis, but recognizing the biological affiliation of the species and rockfish exploitation histories, it would be prudent to maintain yield at ≤500 t for a period sufficiently long to evaluate its suitability (~5 y).

9.4.1 Northwest Vancouver Island Pacific ocean perch (*Sebastes alutus*)

9.4.1.1 Landing Statistics

A major increase (64%) in directed fishing effort for *S. alutus* off the northwest coast of Vancouver Island occurred in 1986 (Table 9.4). This increase was coincident with the adoption of coastwide quotas and trip limits, and their effects were presented by Leaman (1988). The coastwide limits of 1989 have resulted in a substantial increase in effort (+400%) over the comparable 1988 period. Qualified (25%) CPUE increased steadily after 1985 (Fig. 9.9), but has declined slightly in the first half of 1989.

Management of this stock has seldom been effective (Fig. 9.10) and has been particularly poor during periods of coastwide management.

9.4.1.2 Condition of the Stock

There is little information upon which to base an assessment for this area. In spite of large landings in 1986 no biological samples were obtained, primarily because much of the total was landed at U.S. ports. In recent years the area has supported landings of ~250 t/y but the impact of the 1986 fishery is difficult to assess. The increase of qualified CPUE in 1987-1988 was associated with a major reduction in directed effort (-48%). The correlation of CPUE and effort for rockfishes is generally an inverse one, and the CPUE in Area 3D should be closely monitored.

9.4.1.3 Yield Options

The catch history of *S. alutus* in Area 3D suggests that the historical fishery, although it has been brief, has been able to sustain removals of ~250 t/y. The intense *S. alutus* fisheries of the mid-1960s found no significant quantities of fish in Area 3D, hence the virgin biomass must have been considerably less than those of either Queen Charlotte Sound (~80,000 t) or southwest Vancouver Island (~68,000 t). If the biomass was in the 10,000-30,000 t range, then long-term sustainable yield might be ~200-600 t (Table 9.1). Catch statistics have not shown the high levels of nominal or qualified CPUE (>1.5 and 2.0 t/h, respectively) which would be expected if biomass was in the 30,000 t range. For example, CPUE of Pacific ocean perch during the initial stages of fisheries in Moresby Gully and Area 5E(S) (2.0-3.0 t/h) was considerably above that for Area 3D. The decline in 1989 CPUE may indicate that average yields of ~600 t over the 1986-1989 period are not sustainable.

9.5.1 Queen Charlotte Sound/Northwest Vancouver Island redstripe rockfish (Sebastes proriger)

9.5.1.1 Landing Statistics

Historical landings of S. proriger off northwest Vancouver Is. and in Queen Charlotte Sd. were limited until 1986 when over 1000 t were landed (Table 9.5). The reasons for this sudden increase, related to the adoption of coastwide quotas and rapid subscription thereof, were detailed in Leaman (1988). The nominal and qualified CPUE are relatively modest for a new fishery, and have declined over the past three years. Historical catches by foreign trawlers in this area may have been substantial (Leaman et al. 1978). No management has been applied to this stock.

9.5.1.2 Condition of the Stock

There is almost no information upon which to base the assessment of this stock, other than fishery statistics. No biological samples have been obtained in the short period of the fishery. There is clearly uncertainty concerning the condition of this stock, however we caution that it is a Sebastes sp. and therefore extremely vulnerable to exploitation.

9.5.1.3 Yield Options

The yield options for S. proriger in Area 3D/5A are based on published work (Francis 1986) relating initial yields from fisheries to their ultimate long-term yields. Francis estimated that these latter yields seldom exceed 200-300% of initial yields. The average yield from the first six years of the fishery was ~350 t and this may be used as a lower estimate of sustainable yield (Table 9.1). The upper limit would then be estimated at ~900 t (i.e. 250% of 350 t). Stability of quotas over the next 3-5 y may assist in the evaluation of their validity.

9.5.2 Queen Charlotte Sound/Northwest Vancouver Island yellowmouth rockfish (Sebastes reedi)

9.5.2.1 Landing Statistics

The 1986-1987 fisheries recorded major landings of S. reedi from the southern portion of Area 5A and Area 3D (Table 9.6). Much of this removal was associated with the 1986 coastwide quotas and a failure to enforce the 1987 quota through errors in the designation of quota areas. Qualified catch rate rose in 1987 but has since declined. Management of quotas in this area has been consistently poor (Fig. 9.11).

9.5.2.2 Condition of the Stock

No analytic assessments of this stock have been conducted due to a paucity of useful data. It is difficult to determine the effects of fishing, if any, in the absence of these data. The fishery during 1986 and 1987 concentrated on aggregations of spawning females (~76% female) and would be expected to produce high catch rates. The decline in qualified CPUE since 1987 should be regarded with concern and monitored closely.

In Leaman (1988), we indicated that the total mortality rate experienced by the stock, as interpreted through size frequency analysis, appears to be in the appropriate range ($Z=0.05-0.10$). However, we continue to caution that changes in the size frequency of the stock are driven by recruitment and are largely insensitive to short-term fishery effects. Poor adherence to quotas will frustrate an understanding of their validity.

9.5.2.3 Yield Options

The stock of S. reedi in the 3D/5A area has apparently sustained removals of ~200-250 t/y by the domestic fishery. The previous catch history by foreign vessels is less certain due to species designation problems (Leaman et al. 1978). While the upper limit of sustainable yield is unknown, at this time, it would be prudent to limit any expansion of this fishery until the validity of the initial yield options can be verified by fishery results. In addition, the average yield of ~900 t/y since 1986 appears to be generating a declining CPUE. Experience in other rockfish fisheries (Gunderson 1984, Francis 1986) suggests that yields in excess of 200-300% of the initial yields from such fisheries are seldom sustainable. Accordingly, the estimated upper limit for the sustainable yield option from this stock is ~400-750 t (Table 9.1).

9.5.3 Queen Charlotte Sound (QCSd) Pacific ocean perch (Sebastes alutus)

9.5.3.1 Landing Statistics

The fishery in QCSd has been closed to directed fishing until April 1, since 1985. Fishing effort has generally been substantial after that date (Table 9.7). Standardized CPUE has been relatively stable in Goose Island Gully fishery in recent years and has shown a modest increase associated with lower effort in 1989 (Fig. 9.12). Statistics for Mitchell's Gully are of little value in recent years due to the low amount of fishing effort (<200 h). Management of the quota for this stock has been poor in recent years (Fig. 9.13) and the level of catch necessary for rehabilitation of this stock has been exceeded every year since it was identified in 1981.

9.5.3.2 Condition of the Stock

The QCSd S. alutus stock has been analyzed more intensively than any groundfish stock on the Pacific coast and these analyses were reviewed in Leaman (1988). An additional study, employing a Schnute-Deriso age-structured analysis has recently been completed (Polovina, in review). Polovina's analysis yielded optimum F, MSY and biomass estimates identical to those of Archibald et al. (1983). All of these studies have reached the same conclusion, namely that the QCSd S. alutus stocks are severely reduced from their unfished abundance. This conclusion is invariant, derived with a number of independent analytical methods, and supported by the biological characteristics of the stocks. All of the analytic studies have also noted that increased yield from these stocks could be realized if they were rehabilitated to a higher biomass level. While some of these analyses are complex, it is clear that there simply are not as many fish in QCSd as there either once were or should be, if higher yields are desired. Management of the quotas for these stocks has been imprecise and quota overruns have been the rule rather than the exception, since 1983 (Fig. 9.13). It is highly probable that the stocks have continued to decline since the advent of the management program in 1977.

9.5.3.3 Yield Options

As with all rockfish stocks, the dynamics of the Goose Is. Gully stock of S. alutus are relatively slow and rehabilitative management actions of even large measure have little impact over the short term. Previous work (Archibald et al. 1983, Leaman and Stanley 1985) has shown that, with the exception of complete closure, there are relatively small differences in the periods of rehabilitation between F=0.03-0.05. However, increased yields in the future could be realized if fishing mortality on the stocks was decreased (i.e., F<0.06).

The timetable of reconstruction at various levels of fishing mortality has been outlined previously (Archibald et al. 1983).

Present stock biomass is estimated to be in the range of 8000-13000 t, suggested by the simulations using the 1985 and 1977 age compositions, respectively. Yields from these biomasses are dependent on the choice of management policy and have been outlined in previous assessments (Table 9.1, Archibald et al. 1983, Leaman and Stanley 1985). For example only, yields at F=0.06 would range, including the contribution of the Mitchell's Gully component of the stock, from ~700-1000 t. Yields at this level of F are not predicted to produce rehabilitation of the stock.

9.6.1 Moresby Gully Pacific Ocean Perch (Sebastes alutus)

9.6.1.1 Landing Statistics

Catch rates for this stock (Table 9.8) do not display a healthy pattern, in relation to previous experience with rockfish stock histories. There were low catches and catch rates until 1980 when the stock first began to be exploited by the commercial fishery (this stock was discovered by DFO in 1973). After an initial learning period, the fleet began to target the stock heavily and catch rates first rose, then declined. The 1986 catch rate was probably abnormally low, due to effort diversion elsewhere during coastwide quota management. Between 1983-1989 the qualified (25%) catch rate has declined by 46% (Fig. 9.14). Catch statistics therefore suggest negative effects of fishing effort. Quantifying this effect is difficult without a time series encompassing the residency of several cohorts in the fishable stock; such data are unlikely to be available before the 1990s. Management precision for this stock has been better than for any other, and quotas have generally been adhered to (Fig. 9.15).

9.6.1.2 Condition of the Stock

Assessment of the Moresby Gully stock of S. alutus on the basis of cohorts continues to be hampered by the lack of a detailed history of its age composition and the relatively short history of its fishery. It is therefore difficult to detect fishery effects, even when they are present, due to the late age at full recruitment (partial vulnerability is >0.5 only at ages >11 y) and the 'fishing up' effect common to fisheries on this type of species (Francis 1986, Leaman 1987). Present stock assessment relies upon catch statistics and length frequency composition.

The estimation of mortality rates experienced by the stock, as interpreted through length frequency analysis (Stanley 1987a, Rasmussen and Stanley 1988), is compromised by the paucity of samples from the fishery in the latter part of most years. Samples from the spring of the year are composed primarily of smaller fish (mainly males) because mature adults have not yet returned from offshore spawning areas. Mortality rates calculated from such samples will tend to overestimate mortality experienced by the entire stock. The 1988 assessment (Leaman 1988) noted that mortality rates estimated for the stock using 1981-1985 data were inconclusive because of a larger number of smaller fish than would be expected for a constant low mortality rate (Z=0.10).

Length frequency samples from 1989 show a bimodal frequency distribution (Figure 9.16), which is even stronger than that noted in 1987. There has been a steady shift toward smaller fish in the catch since 1981 (Leaman 1988). The enhanced bimodality of 1989 is largely a result of the recruiting 1976 cohort. In addition, there has been a shift toward smaller fish since 1981, such that the larger fish are less abundant. Comparison with length frequencies simulated using growth parameters for this stock and known mortality rates suggest that the stock has experienced a total mortality rate of ~0.20. The target total mortality level for this stock is 0.10 [(M=0.05)+(F=0.05)]. If this pattern is interpreted in terms of the weight distribution of the catch and decreasing catch rates, it can be seen that the larger fish mode has decreased substantially in abundance since 1981 (Leaman 1988).

Catch rates for the S. alutus stock in Moresby Gully are cause for concern. While the 1976 cohort appears stronger than recent cohorts, the decline in CPUE taken in the context of experience with other rockfish stock histories suggests stock decline. The 1976 cohort is now almost fully (80%) recruited to the fishery, yet does not appear to be buffering the declining catch rate. Qualified (25%) CPUE from the 1988 and 1989 summer fisheries has continued the relatively steady decline since 1983 (1986 is considered to be abnormally low due to effects of coastwide quotas).

Management of this stock will continue to be hampered by data limitations and the effects of changing management policies will therefore be difficult to detect and evaluate. The sensitivity of rockfish stocks to high fishing effort argues that any changes in yield should be as relatively small increments applied over time intervals sufficiently long for evaluation of their effects. In the interim, the negative trend in catch rates should be cause for concern.

9.6.1.3 Yield Options

In 1987, an internal Groundfish Section review of the Moresby Gully S. alutus assessment stated that considerably greater yield (3500 t) than was previously identified (2000 t) could be taken from the stock. The present assessment reemphasizes the concerns previously expressed about the condition of the stock. The high-risk yield (3000 t) is based on the alternative 1987 review. The low-risk sustainable yield is estimated as 1900 t (Table 9.1). Management is cautioned that the long delay to full recruitment of a cohort renders most measures of stock status insensitive during the early stages (5-10 y) of rockfish fisheries.

9.6.2 Moresby Gully Redstripe Rockfish (*Sebastes proriger*)

9.6.2.1 Landing Statistics

In concert with other fisheries for *S. proriger*, that in Moresby Gully is of relatively recent origin (Table 9.9). Landings have not yet exceeded 350 t. Qualified (25%) CPUE has been variable since the first significant landings in 1985. No management has been applied to this stock.

9.6.2.2 Condition of the Stock

There is very little information upon which to assess the *S. proriger* stock in Moresby Gully. The size composition of the stock in 1988 was similar to that of 1986-1987 and no adverse effects of the historical fishery are evident. We noted in the 1987 assessment (Leaman 1988) that the mortality rate expressed in the length frequency of the stock was at an appropriate level.

9.6.2.3 Yield Options

Yield from the Moresby Gully stock of *S. proriger* cannot be determined analytically. In the absence of any adverse indications from the limited available data, we assume that the minimum historical landings can be sustained. Indeed, the large stock of *S. alutus* in this area may infer a relatively large stock of *S. proriger*, based on analysis of historical patterns of association between these species (Leaman and Nagtegaal 1987). The catch proportion ratio from that analysis (0.217) implies a yield range of ~350-570 t for *S. proriger* in Moresby Gully (Table 9.1).

9.6.3 Moresby Gully yellowmouth rockfish (*Sebastes reedi*)

9.6.3.1 Landing Statistics

The fishery for *S. reedi* in Moresby Gully has been erratic (Table 9.10). Landings underwent a major increase in 1982 but declined, along with fishing effort, until 1987. Landings in 1989 were slightly below comparable periods of previous years. Both qualified (25%) and unqualified CPUE have been highly variable since 1982. Fleet activity is generally directed at *S. alutus* in this area because CPUE for it is considerably (80-150%) higher. The catch has generally been either well below or well above the quota (Fig. 9.17).

9.6.3.2 Condition of the Stock

There is little information with which to assess the Moresby Gully S. reedi stock. We assume the mean level of harvest is sustainable and represents the minimum level of long-term yield. The association with S. alutus in landings is not as strong as that in Area 5E (Leaman and Nagtegaal 1987), hence catch proportion ratios are inappropriate.

9.6.3.3 Yield Options

The long-term average harvest from this stock (~180t) is assumed to be a lower limit of sustainable yield (Table 9.1). There is little to guide the determination of an upper estimate. We will use the same criterion as in section 9.5.1.3, i.e., 200-300% of initial harvests represents a non-sustainable level (Francis 1986, Gunderson 1984). The upper limit is therefore estimated to be ~500 t.

9.7.2 West Queen Charlotte Islands (south of 54°) Pacific Ocean Perch (Sebastes alutus)

9.7.2.1 Landing Statistics

Landings of S. alutus from Area 5E(S) peaked in 1978 (2413 t) but have since been restricted to much lower levels (Table 9.11). This species has also been managed on the basis of a slope rockfish assemblage, with seasonal openings, from 1983-1986. Since 1987 the seasonal openings, which were designed to optimize individual species yields within the assemblage, were abandoned in favour of quarterly quotas. The effect of this policy was to remove the advantage of seasonal openings in the achievement of an optimal mix of species in the assemblage quota.

Present CPUE (qualified and nominal) for the fishery is well below peak levels and qualified CPUE has declined to the lowest level on record (Fig. 9.18). Management precision for this stock has been affected by assemblage management with S. reedi, and catches have generally been at or above the quota (Fig. 9.19).

9.7.2.2 Condition of the Stock

The 1976 cohort appears to be relatively stronger than recent year recruitments although it does not appear to be as strong as in Moresby Gully. The size frequency of the stock reflected in 1989 samples, when compared to simulated frequencies calculated with known mortality rates (Rasmusson and Stanley 1988), supports the inferences drawn in 1987 and 1989 that the mortality rate for the stock has been consistently above the target value of 0.1 and is closer to 0.2 (Fig. 9.20). There are no other data upon which to examine stock status.

9.7.2.3 Yield Options

The continual decline of qualified CPUE since 1984 and the relatively high mortality rate estimated with size frequency analyses suggest declining stock abundance. The yield options (Table 9.1) are unchanged from 1989 and reflect concern about these features of the stock. Management responded to these concerns by reducing the quota in 1989 from 600 to 400 t.

9.7.3 West Queen Charlotte Islands (south of 54°) Yellowmouth Rockfish (*Sebastes reedi*)

9.7.3.1 Landing Statistics

Landings of *S. reedi* in Area 5E(S) peaked in 1977, declined in 1978 and have been regulated by quota since 1979 (Table 9.12). Nominal CPUE has declined relatively steadily since 1977 and is now <35% of peak levels. Qualified (25%) CPUE has been variable, although it is also well below levels of the late 1970s. After a major resurgence of qualified CPUE in 1986, it has returned to the level of <1.0 t/h recorded in recent years (Fig. 9.21). Achievement of management yield targets has generally been poor (Fig. 9.22), largely resulting from the adoption of quarterly quotas (with a higher percentage of *S. alutus* in the first two quarters) and consequent truncation of the third and fourth openings, and the opportunity to realize greater proportions (and catch rates) of *S. reedi*. Interpretation of catch rates trends is hampered by this seasonal pattern of the fishery.

9.7.3.2 Condition of the Stock

No analytic assessments of this stock have been conducted and few biological samples have been collected. Catch statistics are somewhat more stable than those for *S. alutus* in recent years, however landings have also been below target levels. Comparison of length frequency composition from 1987 commercial samples with that from simulated mortality rates suggests that total mortality rate experienced by this stock has been ≤0.20 (Leaman 1988).

9.7.3.3 Yield Options

Yield options for the *S. reedi* stock in Area 5E(S) remain the same as in 1989 (Table 9.1). Sustainable yield is estimated to range from 400-700 t.

9.7.4 West Queen Charlotte Islands (South of 54°) Rougheye Rockfish (Sebastes aleutianus)

9.7.4.1 Landing Statistics

Landings and fishing effort for S. aleutianus in Area 5E(S) have been erratic since the inception of the fishery in 1977 (Table 9.13). In part, this has occurred due to the grouping of S. aleutianus with the other slope rockfishes for management. Rapid subscription of the S. alutus and S. reedi components of that quota has often truncated fishing for S. aleutianus. S. aleutianus was removed from the slope rockfish quota for Area 5E(S) in 1988 and catch rates have increased over those of the 1984-1987 period. However, they are still below the levels recorded in the early years of the fishery. Catches have been well above quotas since 1986 (Fig. 9.23).

9.7.4.2 Condition of the Stock

A lack of any data except fishery statistics in recent years, hampers assessment of this stock. We have no biological samples more recent than 1979, at which time the age range was extensive (18-72) and the estimated rate of natural mortality low (0.02-0.04) (Archibald et al. 1981). Vital statistics of this level imply relatively low yield potential.

9.7.4.3 Yield Options

The estimated yield options for the S. aleutianus stock in Area 5E(S) reflect the uncertainty of our assessment (Table 9.1), although the generally low level of available yield from the area is recognized. Sustainable yield is estimated to range from 200-300 t.

9.7.5. West Coast Queen Charlotte Islands (South of 54°) Redstripe Rockfish (Sebastes proriger)

9.7.5.1 Landing Statistics

Landings of S. proriger from Area 5E(S) have complemented those of the other slope rockfishes, over the 1980-1989 period (Table 9.14). Directed effort and landings remained low until 1985, when other slope quotas began to be fully subscribed early in the calendar year. For the 1985-1988 period, directed effort (25% qualification) has exceeded 300 h/y and approached that for S. alutus, although qualified CPUE has declined relatively continuously. A major decline in both qualified and nominal CPUE has again been recorded in the first half of 1989 (Fig. 9.24). A similar decline was noted in 1988 and, although CPUE recovered slightly in the latter part of the year, the final figure was down by almost 40% from 1987. No management has been applied to this stock.

9.7.5.2 Condition of the Stock

Assessment information for this stock is limited. Size composition data (Leaman 1988) suggest that the mortality rate experienced by females (~0.15-0.18) is within the appropriate range (0.16-0.20), although that for males (~0.05) is lower than expected. The latter is difficult to account for on the basis of fishery results, unless the fishery is assumed to be sex-specific and/or significant grading of the catch by size is practised. Examination of research samples suggests that male *S. proriger* are indeed more strongly represented in catches than in landings (Nagtegaal and Farlinger 1980, Nagtegaal et al. 1980, Shaw and Archibald 1981).

9.7.2.3 Yield Options

In previous assessments (Leaman 1988,1989) we suggested that the present level of landings (~600 t/y) was unlikely to be sustainable. Cluster analysis of landings from this area (Leaman and Nagtegaal 1987) suggested that the normal catch ratio of *S. proriger* to *S. alutus* was ~0.217. Based on the yield options identified for *S. alutus* (Table 9.1), the estimated level of sustainable yield for *S. proriger* is in the 60-100 t range. These figures may be conservative if the landing patterns, upon which the catch ratio is based, do not accurately reflect the catch of *S. proriger*. There has been no evidence of such market limitations in recent years, although they may have been operative in the late 1970s.

9.8.1 West Queen Charlotte Islands (north of 54°) Rockfish (all *Sebastes*)

9.8.1.1 Introduction

The Langara Spit area (Area 5E(N)) has been the object of an experimental open-fishing program since the fall of 1983. The genesis of this experiment and its purposes were outlined in a previous assessment (Leaman 1988). In 1989, reports of falsification of catch data became so persistent that management announced, but did not enforce, a mandatory observer program for vessels fishing in this area. Data from the experimental area appears to have been contaminated, to an unknown degree, with that from illegal fishing in area 5E(S). This will reduce the long-term value of the experiment and, if it persists, may totally prohibit some aspects of its interpretation. We present here a brief update on the condition of the stocks which are the subjects of this experiment.

9.8.1.2 Landing Statistics

Annual landings increased steadily following the inception of the experiment (Tables 9.15-9.18), before undergoing a substantial decline in 1987. With the exception of S. proriger (Table 9.18), the CPUE (nominal and qualified) for all species has dropped throughout the course of the experiment, until 1989. For all species, present levels of qualified (25%) CPUE are well below peak levels (e.g., Fig. 9.25). Catch rates have improved in 1989, although this improvement is believed to reflect increases accruing from illegal fishing in more productive areas.

The species composition of the catch has changed over the course of the experiment (Fig. 9.26, Table 9.19) as the fleet has moved to alternative species (with lower catch rates) to supplement fishing on the major target, S. alutus, although that species has always comprised the majority of the catch.

9.8.1.3 Condition of the Stocks

The Langara Spit rockfish stocks continue to be in poor condition. Catch rates have decreased continuously since the initiation of the experimental fishery and the biological characteristics of the major target, S. alutus, indicate further depletion of the stock. Age composition samples illustrated that the fishery was based primarily upon fish <10 y old at the outset. These ages are not fully recruited and have only been sexually mature for 1-2 y. The long-term implications of a fishery based on immature and recently mature fish are obvious and serious. The most recent age samples from the commercial fishery (1989) indicate that the fishery during the 1985-1988 period was based almost entirely upon a single cohort. The 1976 cohort represented over 60% of the total numbers of fish in the stock in 1985 (Fig. 9.27). In comparison, this cohort represented only 25% of the numbers (and a far lower proportion of the biomass) of the 5E(S) S. alutus stock at the same time. High fishing mortality has reduced the relative abundance of this cohort to less than 30% of the total in only four years. The same cohort continues to be a dominant feature of the Moresby stock, which has experienced lower fishing pressure. The 1980 cohort, which has shown no general sign of strength in other stocks, is now of the same abundance as the 1976 cohort in the Langara Spit area.

In the previous assessment we noted that this stock appears to have experienced total mortality rates (Z) in excess of 0.50, and close to 0.70. Total mortality on the 1976 cohort appears to be closer to 0.50 (Fig. 9.28). Clearly, such mortality is well above sustainable levels ($Z \approx 0.10$).

In summary, biological characteristics and fishery statistics of the major rockfish stocks in the Langara Spit area indicate continued high mortality rates and poor stock condition. Higher yields from this area could be realized through rehabilitative actions, although a return to maximum long-term yield could take 30-40 y, even with rigorous conservation.

9.8.1.4 Yield Options

Yields of S. alutus in the order of 2000 t/y appear to have generated total mortality rates in the 0.5-0.7 range. If these figures are correct, then sustainable yields ($Z \approx 0.10$) should be in the range of 140-170 t. The upper limits of sustainability are unlikely to be more than twice this figure, and may be less if stock biomass has been reduced below levels giving rise to observed mortality rates. Similar calculations were applied to the average yield of 300 t/y for S. aleutianus. Yield options for S. reedi and S. proriger are simply guideline figures based on Francis' (1986) observations concerning the relationship between initial and long-term yields (see Section 9.5.1.3). Hence, sustainable yields are estimated to be ≈350-500t and 500-700 t, respectively (Table 9.1). A cautionary note concerning the potential yield from these two species should be added. Both species were recorded by observers in catches by Japanese trawlers during 1977 (Leaman et al. 1978). The exact exploitation history for these species is therefore uncertain and yields identified here as those of initial fisheries may overestimate long-term yield, when used in this fashion. Characteristics of these two species in this area will bear careful scrutiny in the future.

The open-fishery component of this experiment was originally proposed to terminate at the end of 1987 and be followed by a second phase, where the process of stock rebuilding at low or no fishing mortality could be initiated. The results of the second phase will be used to provide guidance on management policies for this and other rockfish stocks. Management chose to continue the open-fishery portion of the experiment in 1988 and 1989, to provide further evidence of the negative effects of unrestricted fishing. The decline in stock biomass and the deterioration of all stock status indices as a result of the open fishery have been well demonstrated (Leaman 1988, 1989). Incremental scientific benefits from continued open fishing are expected to be very small.

Table 9.1. Yield options for slope rockfishes off the British Columbia coast for 1990.

Species	Area	Conservative	Yield Options (t) Sustainable (Low risk - High risk)	Non-sustainable
S. alutus	3C	<100	100 - 200	>200
S. proriger	"	<200	200 - 1000	>1000
S. alutus	3D	<200	200 - 600	>600
S. reedi	3D/5A	<250	250 - 750	>750
S. proriger	"	<350	350 - 900	>900
S. alutus	5A/B	<700	700 - 1000	>1000
S. alutus	Moresby	<1900	1900 - 3000	>3000
S. reedi	"	<160	160 - 500	>500
S. proriger	"	<350	350 - 570	>570
S. alutus	5E(S)	<300	300 - 500	>500
S. reedi	"	<400	400 - 700	>700
S. aleutianus	"	<200	200 - 300	>300
S. proriger	"	<50	50 - 100	>100
Slope rockfish[1]				
Jan.-June	"	<300	300 - 500	>500
Sep.-Dec.	"	<600	600 - 1000	>1000
S. alutus	5E(N)	<150	150 - 170	>250
S. reedi	"	<350	350 - 500	>500
S. aleutianus	"	<50	50 - 100	>100
S. proriger	"	<500	500 - 700	>700
Slope rockfish[2]	"	<200	200 - 270	>270

[1] *S. alutus*, *S. reedi*, and *S. aleutianus*

[2] *S. alutus* and *S. aleutianus*

Table 9.2. Canadian landing statistics for Pacific ocean perch off southwest Vancouver Island (including Mgmt Area 125).

YEAR	Total landings	0% Qualification L	E	CPUE	25% Qualification L	E	CPUE
	4.47	4.47	6.50	.688	4.28	4.50	.951
1968	.12	.12	6.30	.019	–	–	–
	–	–	–	–	–	–	–
1970	298.84	297.77	444.80	.669	273.11	293.20	.931
	206.99	201.14	552.00	.364	190.50	333.70	.571
1972	72.24	13.25	21.30	.622	12.67	14.30	.886
	–	–	–	–	–	–	–
1974	–	–	–	–	–	–	–
	5.46	5.46	166.50	.033	1.46	7.00	.209
1976	1.29	1.29	5.00	.258	.87	1.00	.870
	15.04	13.81	447.50	.031	8.67	42.30	.205
1978	48.88	48.57	57.80	.840	47.51	32.00	1.485
	80.62	79.91	147.10	.543	77.14	44.90	1.718
1980	285.59	284.77	448.20	.635	277.93	234.90	1.183
	381.54	364.99	750.80	.486	341.61	430.50	.794
1982	395.23	372.29	740.30	.503	342.56	430.70	.795
	373.97	179.30	348.30	.515	167.71	143.30	1.170
1984	406.17	317.39	481.90	.659	316.86	478.80	.662
	243.11	222.85	1079.60	.206	195.86	692.70	.283
1986	242.15	178.52	547.70	.326	140.49	185.10	.759
	542.27	414.95	655.60	.633	340.10	366.90	.927
1988	307.46	208.52	1812.40	.115	77.64	228.80	.339
[a]	198.20	152.58	1449.20	.105	83.58	266.00	.314

% qualification = % alutus in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
[a] to 1/8/89

Table 9.3. Canadian landing statistics for redstripe rockfish in Area 3C.

	Total	0% Qualification			25% Qualification		
YEAR	landings	L	E	CPUE	L	E	CPUE
1980	.29	.29	1.00	.290	-	-	-
	12.76	12.76	10.50	1.215	9.32	4.30	2.167
1982	2.53	2.53	50.30	.050	2.42	1.80	1.344
	30.07	24.63	292.10	.084	11.66	31.30	.373
1984	34.57	11.01	331.10	.033	3.71	3.20	1.159
	61.01	44.16	406.50	.109	19.37	44.50	.435
1986	514.72	368.19	1724.10	.214	241.19	286.50	.842
	377.13	325.11	1299.00	.250	199.50	224.30	.889
1988	392.87	373.51	1607.40	.232	234.95	318.10	.739
[a]	122.20	106.69	784.00	.136	62.51	216.80	.288

% qualification = % proriger in catch needed for inclusion of data

L = Landings (t)

E = Effort (h)

CPUE = Nominal catch per unit effort (t/h)

[a] to 1/8/89

Table 9.4. Canadian landing statistics for Pacific ocean perch off northwest Vancouver Island (Area 3D).

YEAR	Total landings	0% Qualification L	E	CPUE	25% Qualification L	E	CPUE
	2.55	2.55	10.00	.255	2.55	10.00	.255
1968	.41	.04	66.50	.001	-	-	-
	2.49	2.49	40.50	.061	1.26	12.50	.101
1970	5.38	5.38	150.60	.036	-	-	-
	11.39	11.39	82.00	.139	10.32	67.00	.154
1972	45.02	-	-	-	-	-	-
	-	-	-	-	-	-	-
1974	2.92	2.92	59.00	.049			-
	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	-
	1.13	1.13	7.30	.155	.14	4.00	.035
1978	7.05	4.48	18.90	.237	3.45	6.90	.500
	44.24	44.24	53.90	.821	43.89	40.80	1.076
1980	144.26	143.50	300.90	.477	126.80	190.10	.667
	165.97	165.97	353.40	.470	163.40	283.40	.577
1982	112.86	112.13	200.80	.558	109.92	124.30	.884
	463.33	214.39	574.30	.373	182.58	281.60	.648
1984	337.40	236.03	441.80	.534	231.60	353.30	.656
	312.69	262.51	506.40	.518	217.59	356.40	.611
1986	1045.95	658.23	815.00	.808	611.16	585.80	1.043
	450.49	414.95	655.60	.633	363.23	304.70	1.192
1988	491.86	464.87	666.60	.697	415.61	332.40	1.251
[a]	471.27	449.51	598.20	.751	415.05	440.50	.942

% qualification = % alutus in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
[a] to 1/8/89

Table 9.5. Canadian landing statistics for redstripe rockfish in Queen Charlotte Sound - northwest Vancouver Island.

YEAR	Total landings	0% Qualification L	0% Qualification E	0% Qualification CPUE	25% Qualification L	25% Qualification E	25% Qualification CPUE
1980	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
1982	2.58	2.58	121.00	.021	-	-	-
	40.76	38.25	139.40	.274	36.63	1.30	28.177
1984	49.37	15.66	281.90	.056	2.01	5.50	.365
	124.60	84.55	935.40	.090	45.27	197.00	.230
1986	1062.44	974.59	1932.80	.504	797.72	679.80	1.173
	1344.80	1230.43	2118.70	.581	996.35	830.80	1.199
1988	602.98	588.64	1962.30	.300	432.90	545.80	.793
[a]	463.53	387.48	1187.00	.326	275.17	414.30	.664

% qualification = % proriger in catch needed for inclusion of data

L = Landings (t)

E = Effort (h)

CPUE = Nominal catch per unit effort (t/h)

[a] to 1/8/89

Table 9.6. Canadian landing statistics for yellowmouth rockfish in Queen Charlotte Sound - northwest Vancouver Island.

	Total	0% Qualification			25% Qualification		
YEAR	landings	L	E	CPUE	L	E	CPUE
	5.35	5.35	31.50	.170	-	-	-
1972	-	-	-	-	-	-	-
	176.65	176.65	37.00	4.774	176.21	32.50	5.422
1974	78.91	78.91	23.00	3.431	78.91	23.00	3.431
	1.08	1.08	34.50	.031	-	-	-
1976	12.29	12.29	10.00	1.229	12.29	10.00	1.229
	335.89	335.89	466.00	.721	331.29	226.30	1.464
1978	16.54	16.54	110.00	.150	10.86	16.00	.679
	10.25	10.25	102.00	.100	6.49	9.70	.669
1980	27.92	27.92	97.50	.286	24.77	32.70	.757
	4.74	4.74	25.60	.185	.07	2.00	.035
1982	227.89	176.94	167.50	1.056	163.42	39.80	4.106
	628.09	460.12	501.50	.917	367.12	151.40	2.425
1984	458.27	201.59	405.10	.498	182.28	214.60	.849
	716.91	337.90	854.90	.395	292.01	204.50	1.428
1986	1208.37	944.84	1247.40	.757	817.10	546.10	1.496
	1170.14	1075.16	1307.50	.822	907.37	417.10	2.175
1988	574.48	571.18	1865.50	.306	430.98	329.00	1.310
[a]	468.68	436.84	930.50	.469	353.53	288.80	1.224

% qualification = necessary % reedi in catch for inclusion of data
L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
[a] to 1/8/89

Table 9.7. Total landings (foreign and domestic) of Pacific ocean perch, standardized CPUE and calculated total effort on principal fishing grounds of Queen Charlotte Sound. (Fishery changed to a winter fishery on spawning females 1983-1985.)

	Goose Island Gully			Mitchell's Gully		
Year	Total landings	Standard. CPUE	Calculated effort	Total landings	Standard. CPUE	Calculated effort
	1890	.836	2261	-	-	-
1960	1679	.698	2405	-	-	-
	1199	.797	1504	-	-	-
	1838	1.161	1583	-	-	-
	3712	1.457	2548	-	-	-
	3450	1.134	3042	57	-	-
1965	7478	1.491	5015	488	.780	626
	20752	1.441	14401	1369	.815	1680
	12119	1.068	11347	5319	1.157	4597
	10213	1.045	9773	2556	1.137	2248
	6872	.763	9007	2945	.995	2960
1970	6489	.672	9657	1296	1.010	1283
	3455	.526	6568	813	.954	852
	5645	.829	6809	995	.854	1165
	3755	.773	4858	2264	1.351	1676
	7269	.773	9404	1917	.974	1968
1975	4209	.507	8302	1151	.989	1164
	2442	.733	3332	576	.673	856
	1693	.660	2565	256	.551	465
	865	.821	1054	375	.817	459
	951	.799	1190	480	.670	716
1980	1226	.932	1316	305	.862	354
	801	.760	1054	680	4.474	152
	570	.514	1110	286	2.648	108
	1215	1.257	967	31	.929	33
	841	2.017	417	19	.594	32
1985	743	.475	1565	80	.149	537
	623	.534	1167	-	-	-
	1548	.518	2989	98	.506	193
	978	.572	1710	208	.507	411
[a]	632	.736	859	81	.356	226

[a] to 1/8/89

Table 9.8. Canadian landing statistics for Pacific ocean perch in Moresby Gully.

YEAR	Total landings	0% Qualification L	0% Qualification E	0% Qualification CPUE	25% Qualification L	25% Qualification E	25% Qualification CPUE
1968	1.13	1.13	3.50	.323	1.13	3.50	.323
1969	.78	.78	23.80	.033	-	-	-
1970	27.35	25.58	594.30	.043	3.75	10.50	.357
1971	9.78	9.78	346.30	.028	1.62	8.50	.191
1972	13.18	13.18	567.10	.023	-	-	-
1973	37.93	34.21	672.90	.051	20.33	15.80	1.287
1974	36.30	34.97	595.50	.059	21.52	16.30	1.320
1975	116.53	107.25	1023.00	.105	93.64	91.30	1.026
1976	85.64	70.51	2185.00	.032	40.18	107.00	.376
1977	73.72	34.75	1788.00	.019	11.97	48.50	.247
1978	175.90	175.90	996.40	.177	126.63	82.60	1.533
1979	369.67	354.70	2046.00	.173	276.02	457.00	.604
1980	2544.95	2247.51	2259.20	.995	2232.59	1607.50	1.389
1981	2216.64	1523.91	1782.10	.855	1487.78	1009.20	1.474
1982	3625.58	2733.06	1846.00	1.481	2694.44	1282.80	2.100
1983	2219.99	1507.05	853.80	1.765	1503.57	668.70	2.248
1984	2055.02	1286.64	1578.70	.815	1269.42	693.10	1.832
1985	1967.25	1330.05	1593.70	.835	1275.72	740.60	1.723
1986	628.66	623.39	1239.70	.503	562.83	492.10	1.144
1987	1910.85	1809.87	1676.30	1.080	1775.03	1313.20	1.352
1988	3106.78	3057.38	2759.40	1.108	3005.86	2301.00	1.306
[a]	900.13	886.55	999.50	.887	857.71	704.40	1.218

% qualification = necessary % *alutus* in catch for inclusion of data

L = Landings (t)

E = Effort (h)

CPUE = Nominal catch per unit effort (t/h)

[a] to 1/8/89

Table 9.9. Canadian landing statistics for redstripe rockfish in Moresby Gully.

	Total	0% Qualification			25% Qualification		
YEAR	landings	L	E	CPUE	L	E	CPUE
1980	19.32	19.32	193.00	.100	1.26	6.50	.194
	5.32	3.94	116.70	.034	-	-	-
1982	22.83	17.67	286.40	.062	2.12	5.50	.385
	19.94	15.72	107.80	.146	6.20	25.10	.247
1984	70.52	33.08	409.40	.081	18.52	41.20	.450
	180.83	152.72	544.40	.281	96.82	141.80	.683
1986	109.61	106.97	507.50	.211	51.29	125.00	.410
	306.72	289.49	800.80	.362	176.35	245.90	.717
1988	199.81	196.21	1244.30	.158	78.20	191.50	.408
[a]	150.84	148.96	556.10	.271	69.89	126.30	.553

% qualification = % *proriger* in catch for inclusion of data
L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)

[a] to 1/8/89

Table 9.10. Canadian landing statistics for yellowmouth rockfish in Moresby Gully.

YEAR	Total landings	0% Qualification L	E	CPUE	25% Qualification L	E	CPUE
1978	91.94	91.94	54.30	1.693	84.65	45.20	1.873
	20.48	20.48	37.60	.545	-	-	-
1980	20.13	20.13	28.70	.701	1.50	5.50	.273
	109.67	40.95	116.60	.351	-	-	-
1982	417.32	325.15	711.60	.457	228.75	202.10	1.132
	202.04	78.24	239.70	.326	15.22	39.80	.382
1984	338.09	106.12	308.10	.344	34.73	50.20	.692
	232.01	177.51	342.90	.518	114.20	85.80	1.331
1986	100.28	100.28	226.80	.442	64.46	72.50	.889
	116.40	74.80	459.00	.163	34.43	56.30	.612
1988	324.71	321.76	924.00	.348	167.84	114.50	1.466
a	66.09	66.09	290.01	.228	-	-	-

% qualification = % *reedi* in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
[a] to 1/8/89

Table 9.11. Canadian landing statistics for Pacific ocean perch in Area 5E (S).

	Total	0% Qualification			25% Qualification		
YEAR	landings	L	E	CPUE	L	E	CPUE
1976	78.78	78.78	59.00	1.335	78.78	59.00	1.335
	1549.42	1475.24	1041.50	1.416	1321.29	651.40	2.028
1978	2413.70	2346.93	1043.90	2.248	2255.89	724.40	3.114
	839.28	839.28	557.40	1.506	823.09	376.10	2.188
1980	876.96	472.90	496.20	.953	449.31	332.50	1.351
	599.21	432.73	235.70	1.836	412.99	172.50	2.394
1982	614.11	606.73	443.10	1.369	550.38	308.80	1.782
	835.17	762.67	629.80	1.211	721.46	403.80	1.787
1984	840.88	457.92	344.80	1.328	434.90	215.90	2.014
	828.61	603.93	691.50	.873	562.91	453.80	1.240
1986	641.91	473.78	733.50	.646	341.09	275.40	1.239
	660.94	553.32	834.60	.663	485.83	453.30	1.072
1988	766.52	724.24	1081.40	.670	664.29	586.20	1.133
a	323.09	321.17	395.10	.813	305.28	286.30	1.066

% qualification = % alutus in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
[a] to 1/8/89

Table 9.12. Canadian landing statistics for yellowmouth rockfish in Area 5E (S).

YEAR	Total landings	0% Qualification L	0% Qualification E	0% Qualification CPUE	25% Qualification L	25% Qualification E	25% Qualification CPUE
1976	-	-	-	-	-	-	-
	1256.74	1256.74	583.00	2.156	1226.64	438.20	2.799
1978	1104.64	1104.64	600.40	1.840	858.89	296.30	2.899
	388.54	388.54	356.50	1.090	328.72	204.70	1.606
1980	499.91	477.23	321.50	1.484	477.23	321.50	1.484
	922.41	380.12	192.20	1.978	350.89	129.90	2.701
1982	414.39	351.87	335.90	1.048	307.98	191.90	1.605
	588.21	556.22	575.50	.966	501.10	356.70	1.405
1984	441.08	212.33	336.20	.632	169.75	178.90	.949
	495.77	344.95	609.80	.566	220.00	257.80	.853
1986	564.49	538.46	489.30	1.100	466.77	240.10	1.944
	450.59	395.39	714.30	.554	318.68	267.60	1.191
1988	289.37	283.69	817.00	.347	181.66	149.40	1.216
a	157.92	157.92	278.30	.568	138.02	149.30	.930

% qualification = % *reedi* in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
[a] to 1/8/89

Table 9.13. Canadian landing statistics for rougheye rockfish in Area 5E (S).

YEAR	Total landings	0% Qualification L	E	CPUE	25% Qualification L	E	CPUE
1976	-	-	-	-	-	-	-
	76.28	76.28	134.50	.567	74.69	66.00	1.132
1978	139.49	139.49	396.90	.351	105.17	118.30	.889
	192.09	192.09	347.70	.552	159.51	137.10	1.163
1980	51.42	51.42	60.00	.857	50.31	23.00	2.187
	9.93	9.93	46.20	.215	5.13	7.20	.713
1982	274.38	274.38	269.30	1.019	262.55	156.20	1.681
	74.16	61.37	324.10	.189	26.70	22.00	1.214
1984	100.85	73.37	215.30	.341	21.49	24.20	.888
	157.86	115.67	411.90	.281	77.52	178.30	.435
1986	268.77	165.56	371.60	.446	89.55	158.30	.566
	296.11	260.53	702.20	.371	226.54	414.20	.547
1988	353.99	353.99	857.80	.412	313.02	466.30	.671
a	130.76	130.76	375.80	.348	93.01	120.80	.770

% qualification = % *aleutianus* in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
[a] to 1/8/89

Table 9.14. Canadian landing statistics for redstripe rockfish in Area 5E (S).

	Total	0% Qualification			25% Qualification		
YEAR	landings	L	E	CPUE	L	E	CPUE
1980	110.96	110.96	310.10	.358	64.70	77.90	.831
	132.63	81.01	148.60	.545	44.51	35.50	1.254
1982	33.55	31.10	210.70	.148	5.45	9.00	.606
	142.79	132.13	316.10	.418	76.31	96.60	.790
1984	148.45	85.11	212.30	.401	45.26	22.20	2.039
	918.73	763.12	708.10	1.078	713.17	439.80	1.622
1986	728.23	588.80	637.80	.923	459.01	318.00	1.443
	628.94	607.25	638.70	.951	554.61	358.00	1.549
1988	516.77	494.15	867.10	.570	410.06	431.60	.950
a	68.60	68.60	226.70	.303	24.04	35.80	.672

% qualification = % proriqer in catch for inclusion of data
L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
[a] to 1/8/89

Table 9.15. Canadian landing statistics for Pacific ocean perch in Area 5E (N).

YEAR	Total landings	0% Qualification L	0% Qualification E	0% Qualification CPUE	25% Qualification L	25% Qualification E	25% Qualification CPUE
1976	-	-	-	-	-	-	-
	1.42	1.42	19.70	.072	.70	2.30	.304
1978	22.22	22.22	151.10	.147	6.65	16.80	.396
	227.49	227.49	177.50	1.282	223.83	108.50	2.063
1980	84.56	84.56	119.30	.709	64.80	39.50	1.641
	109.22	63.58	32.40	1.962	53.15	24.10	2.205
1982	342.23	218.48	144.10	1.516	194.18	109.30	1.777
	291.98	226.43	401.80	.564	208.28	193.50	1.076
1984	2173.86	1819.93	1213.50	1.500	1779.38	980.00	1.816
	1921.21	1821.61	1908.70	.954	1712.09	1514.50	1.130
1986	2725.37	2658.69	2957.40	.899	2558.46	2319.30	1.103
	1129.70	1048.62	1294.00	.810	1015.88	1119.60	.907
1988	1088.79	1088.79	1657.70	.650	1027.99	1373.60	.748
a	1195.95	1097.02	1220.30	.899	1069.48	996.10	1.107

% qualification = % *alutus* in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
[a] to 1/8/89

Table 9.16. Canadian landing statistics for yellowmouth rockfish in Area 5E (N).

YEAR	Total landings	0% Qualification L	0% Qualification E	0% Qualification CPUE	25% Qualification L	25% Qualification E	25% Qualification CPUE
1976	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
1978	-	-	-	-	-	-	-
	16.86	16.86	69.90	.241	4.08	4.10	.995
1980	-	-	-	-	-	-	-
	2.34	2.34	4.90	.478	2.34	4.90	.478
1982	67.88	54.58	70.30	.776	52.36	36.50	1.435
	52.23	18.36	44.50	.413	3.48	9.00	.387
1984	72.84	63.05	468.30	.135	15.79	14.90	1.060
	179.88	173.60	1008.30	.172	55.12	40.50	1.361
1986	614.97	608.05	2151.90	.283	403.15	511.30	.788
	108.91	105.46	652.40	.162	66.19	89.70	.738
1988	107.18	107.18	943.10	.114	48.72	74.20	.657
a	114.06	114.06	397.20	.287	87.56	81.90	1.069

% qualification = % *reedi* in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
[a] to 1/8/89

Table 9.17. Canadian landing statistics for rougheye rockfish in Area 5E (N).

	Total	0% Qualification			25% Qualification		
YEAR	landings	L	E	CPUE	L	E	CPUE
1976	-	-	-	-	-	-	-
	-	-	-	-	-	-	-
1978	-	-	-	-	-	-	-
	13.99	13.99	139.50	.100	9.73	64.10	.152
1980	2.58	2.58	42.50	.061	-	-	-
	98.08	98.08	26.00	3.772	94.20	23.00	4.096
1982	69.09	69.09	74.40	.929	65.66	34.80	1.887
	27.46	84.01	271.50	.309	43.39	44.30	.979
1984	226.21	207.86	824.70	.252	93.50	134.30	.696
	453.67	453.25	1344.40	.337	310.64	397.20	.782
1986	460.81	430.00	1627.30	.264	264.83	338.90	.781
	179.86	176.26	946.70	.186	89.79	154.20	.582
1988	466.96	466.96	1505.50	.310	331.78	632.70	.524
a	309.37	309.37	970.70	.309	212.94	322.80	.660

% qualification = % *aleutianus* in catch needed for inclusion of data
L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
[a] to 1/8/89

Table 9.18. Canadian landing statistics for redstripe rockfish in Area 5E (N).

YEAR	Total landings	0% Qualification L	0% Qualification E	0% Qualification CPUE	25% Qualification L	25% Qualification E	25% Qualification CPUE
1980	-	-	-	-	-	-	-
	.33	.33	4.90	.067	-	-	-
1982	13.27	6.43	35.30	.182	-	-	-
	18.44	3.14	17.50	.179	-	-	-
1984	110.85	108.31	552.10	.196	27.45	18.50	1.484
	258.99	258.99	1153.50	.225	93.53	98.30	.951
1986	716.62	711.98	2366.90	.301	474.57	314.00	1.511
	224.29	214.13	929.80	.230	103.78	186.10	.558
1988	113.92	113.92	1193.60	.095	34.02	57.70	.590
a	127.26	115.76	451.20	.257	47.91	67.10	.717

% qualification = % proriger in catch for inclusion of data
L = Landings (t)
E = Effort (h)
CPUE = Nominal catch per unit effort (t/h)
^{a}to 1/8/89

Table 9.19. Catches and percentages of rockfish for the major species in the fishery for Minor Area 35, 1976-1988.

Year	Total rockfish	*aleutianus*	*alutus*	*brevispinis*	*proriger*	*reedi*
1976	-	-	-	-	-	-
	5.51	-	1.42/ 25.77	-	-	-
1978	48.22	-	22.22/ 46.08	15.70/ 32.56	-	-
	287.27	13.99/ 4.87	227.49/ 79.19	7.77/ 2.70	4.76/ 1.66	16.86/ 5.87
1980	105.05	2.58/ 2.46	84.56/ 80.50	15.45/ 14.71	-/	-/ .00
	376.13	98.08/ 26.08	109.22/ 29.04	2.26/ .60	.33/ .09	2.34/ .62
1982	691.53	69.09/ 9.99	342.23/ 49.49	37.57/ 5.43	13.27/ 1.92	67.88/ 9.82
	568.18	127.46/ 22.43	291.98/ 51.39	16.32/ 2.87	18.44/ 3.25	52.23/ 9.19
1984	2995.78	226.97/ 7.58	2186.33/ 72.98	248.34/ 8.29	110.85/ 3.70	72.80/ 2.43
	3230.61	465.37/ 14.41	1938.46/ 60.00	244.68/ 7.57	259.00/ 8.02	180.31/ 5.58
1986	4968.30	431.30/ 8.68	2727.20/ 54.89	165.80/ 3.34	707.30/ 14.24	620.40/ 12.5
	1880.18	179.86/ 9.57	1129.70/ 60.08	84.87/ 4.51	224.29/ 11.93	108.91/ 5.79
1988	2134.51	466.96/ 21.88	1088.79/ 51.01	130.71/ 6.12	113.92/ 5.34	107.18/ 5.02
[a]	2042.92	309.37/ 15.14	1195.95/ 58.54	196.23/ 9.61	127.26/ 6.23	114.06/ 5.58

[a] to 1/8/89

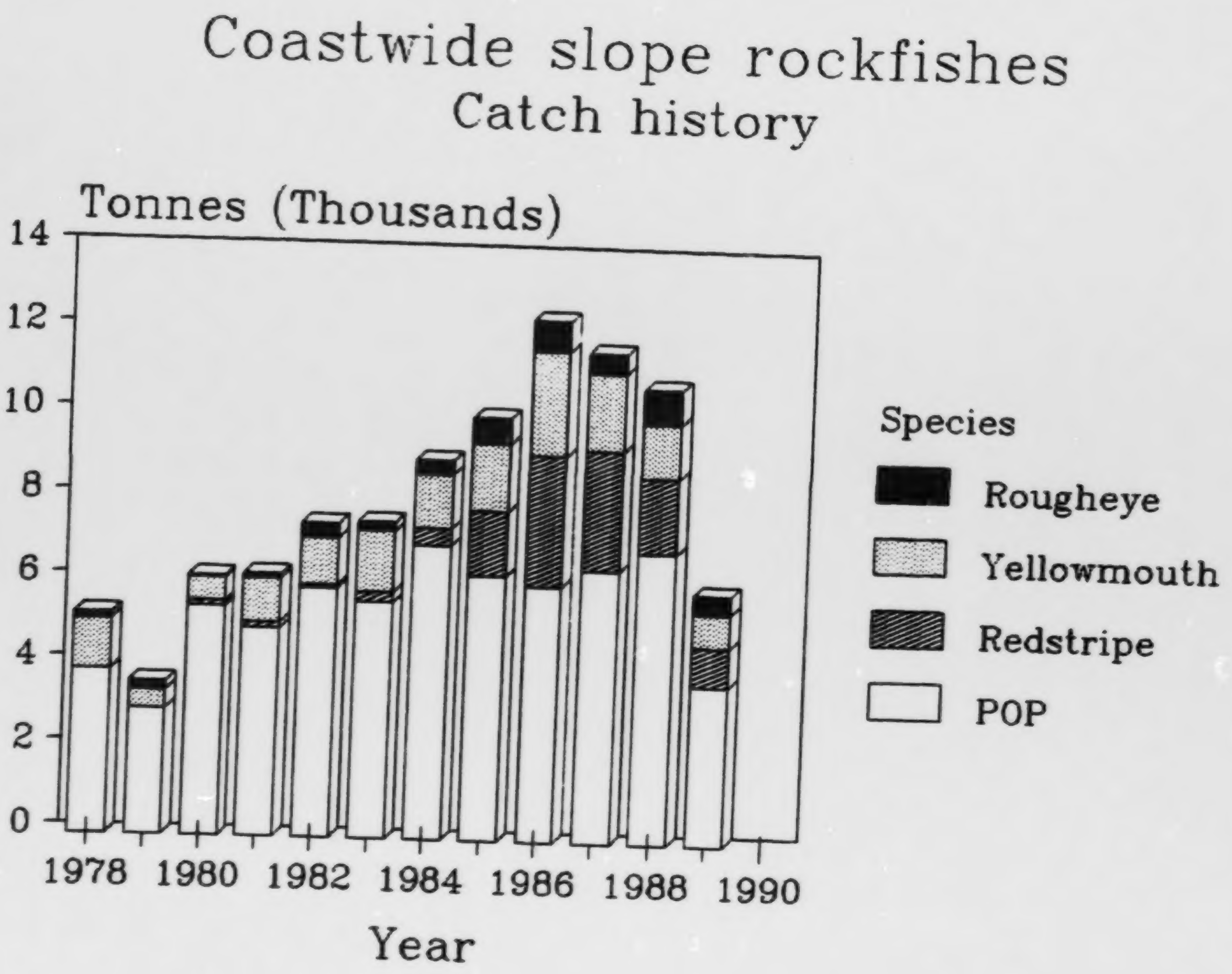


Fig. 9.1. Species composition of coastwide slope rockfish catches, 1978-1989.
]

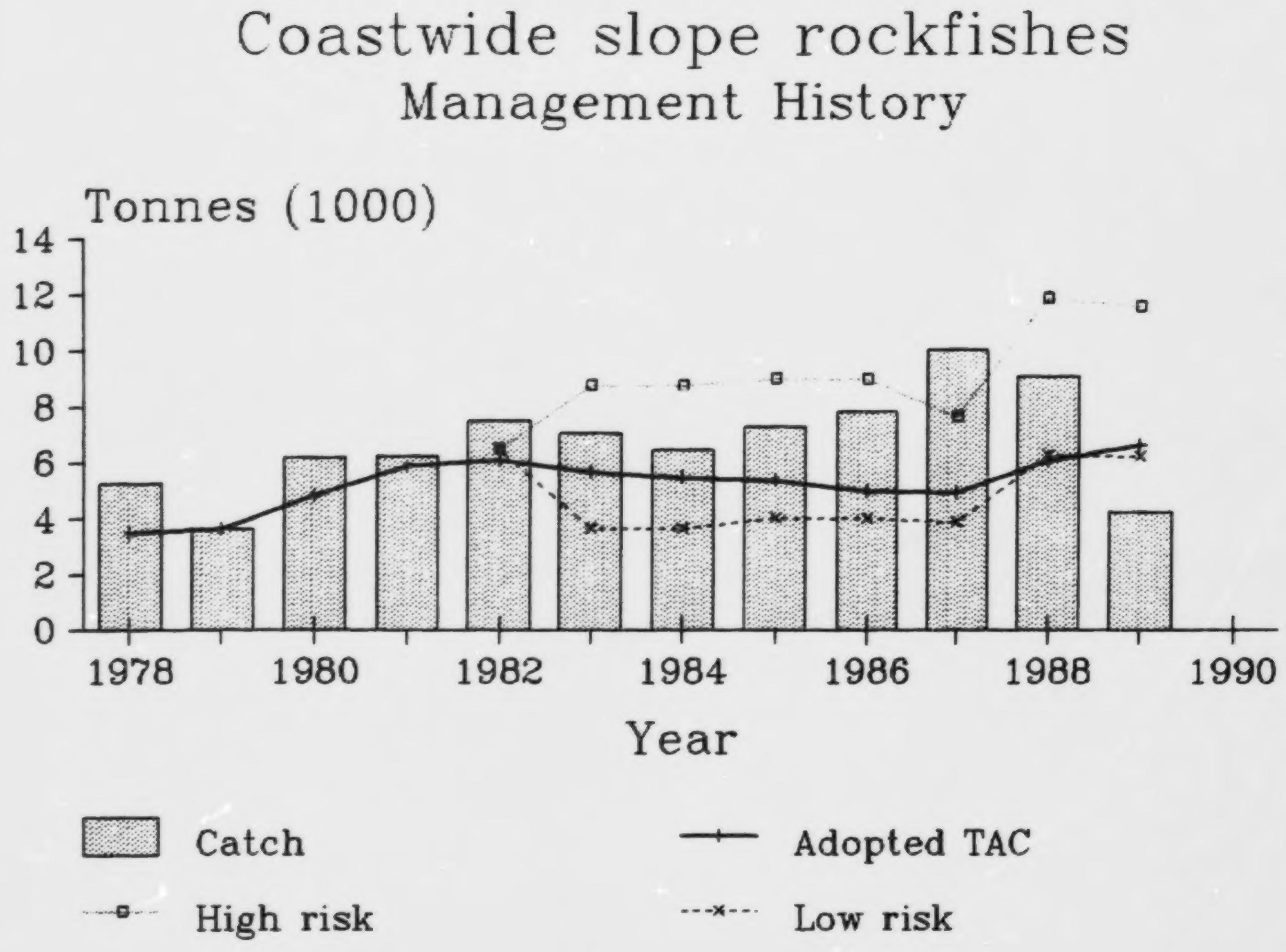


Fig. 9.2. History of coastwide slope rockfish management, 1978-1989. High risk and low risk figures are recommended yield options. Langara experimental fishery data excluded.

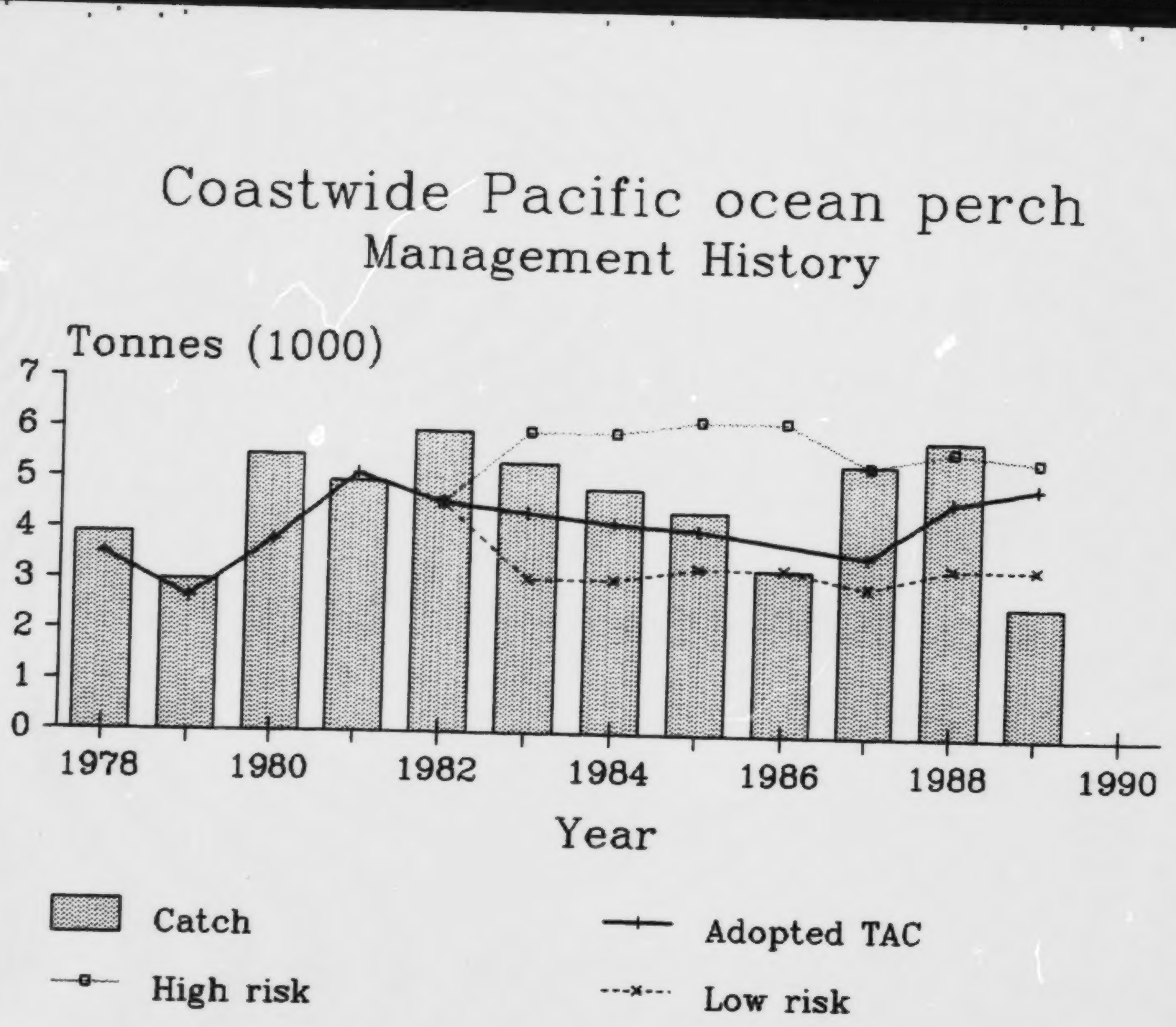


Fig. 9.3. History of coastwide Pacific ocean perch management, 1978-1989. High risk and low risk figures are recommended yield options. Langara experimental fishery data excluded.

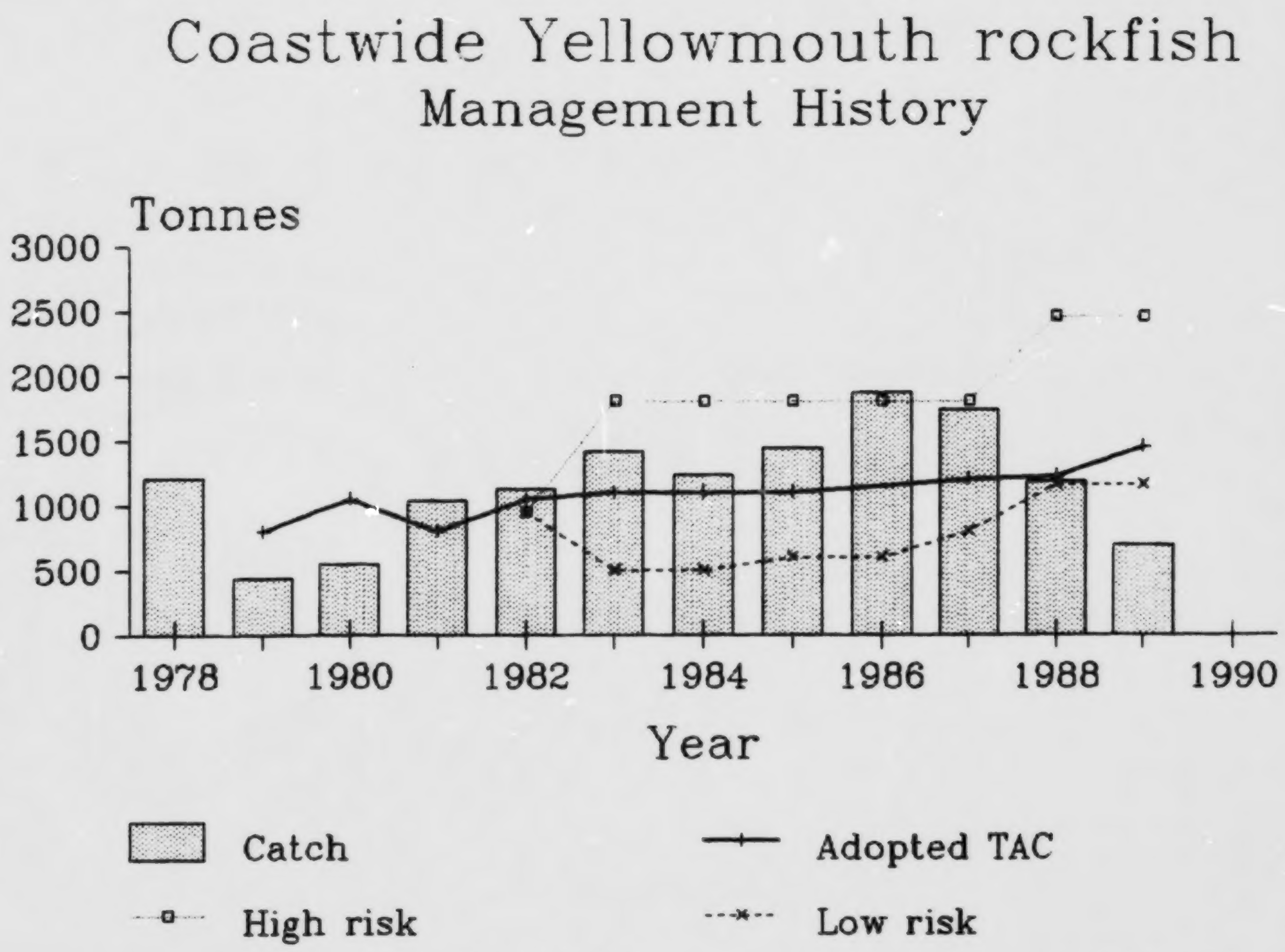


Fig. 9.4. History of coastwide yellowmouth rockfish management, 1978-1989. High risk and low risk figures are recommended yield options. Langara experimental fishery data excluded.

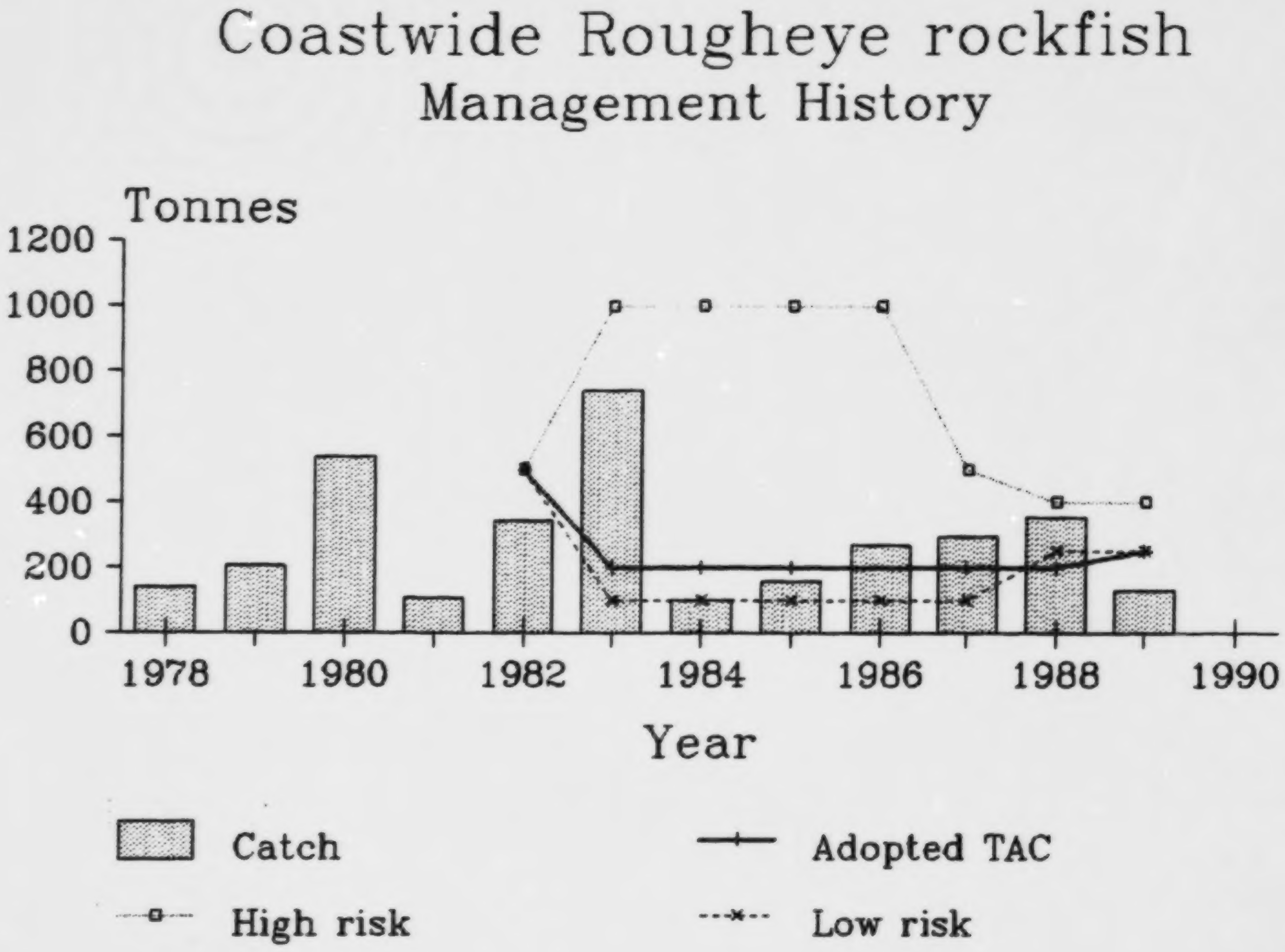


Fig. 9.5. History of coastwide rougheye rockfish management, 1978-1989. High risk and low risk figures are recommended yield options. Langara experimental fishery data excluded.

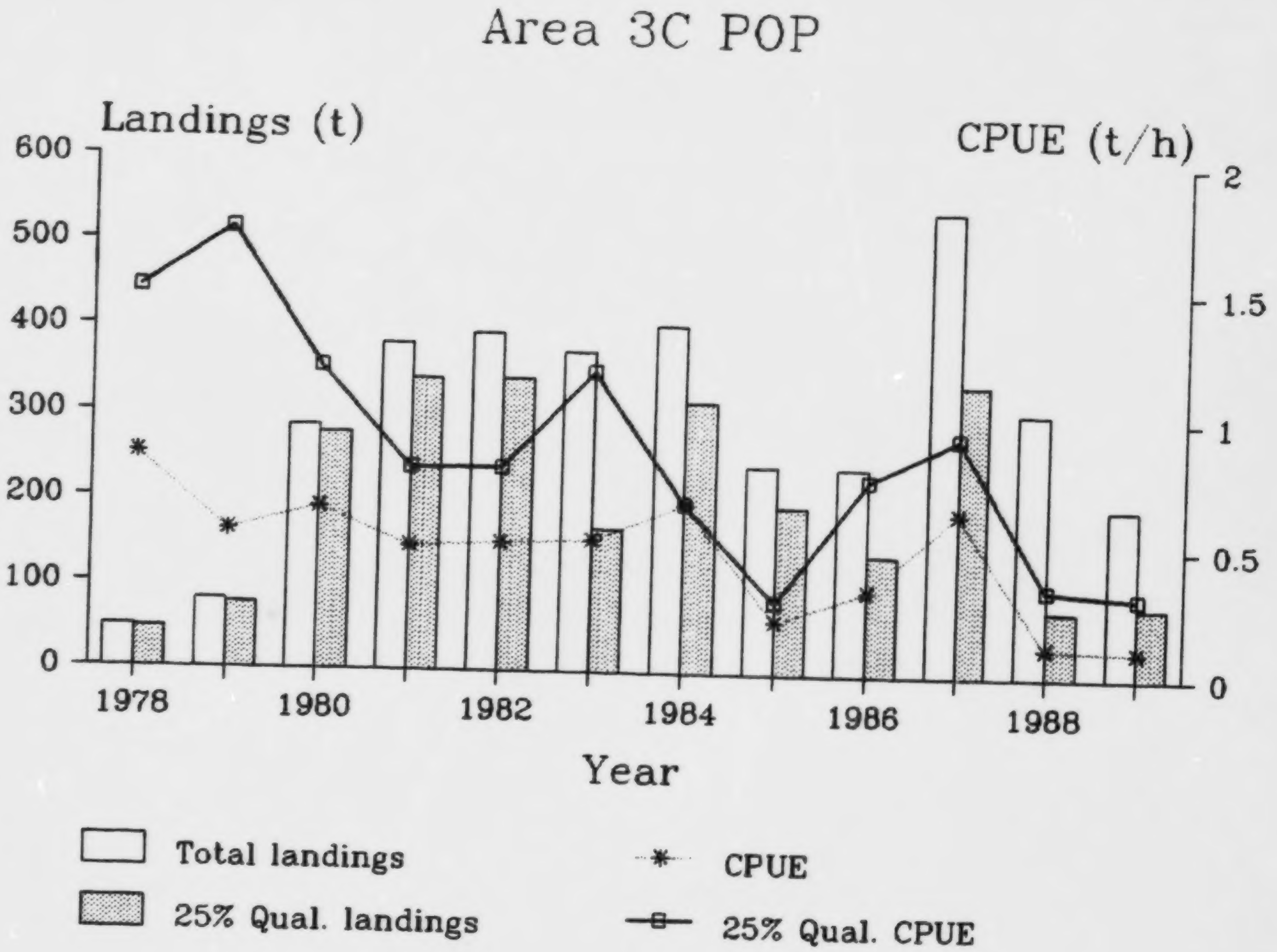


Fig. 9.6. Catch and catch per unit effort (CPUE) for Pacific ocean perch (*Sebastes alutus*, Pacific ocean perch) off southwest Vancouver Island (Area 3C + Area 125), 1978-1939. Qualified statistics include data where ≥ 25% of catch was Pacific ocean perch.

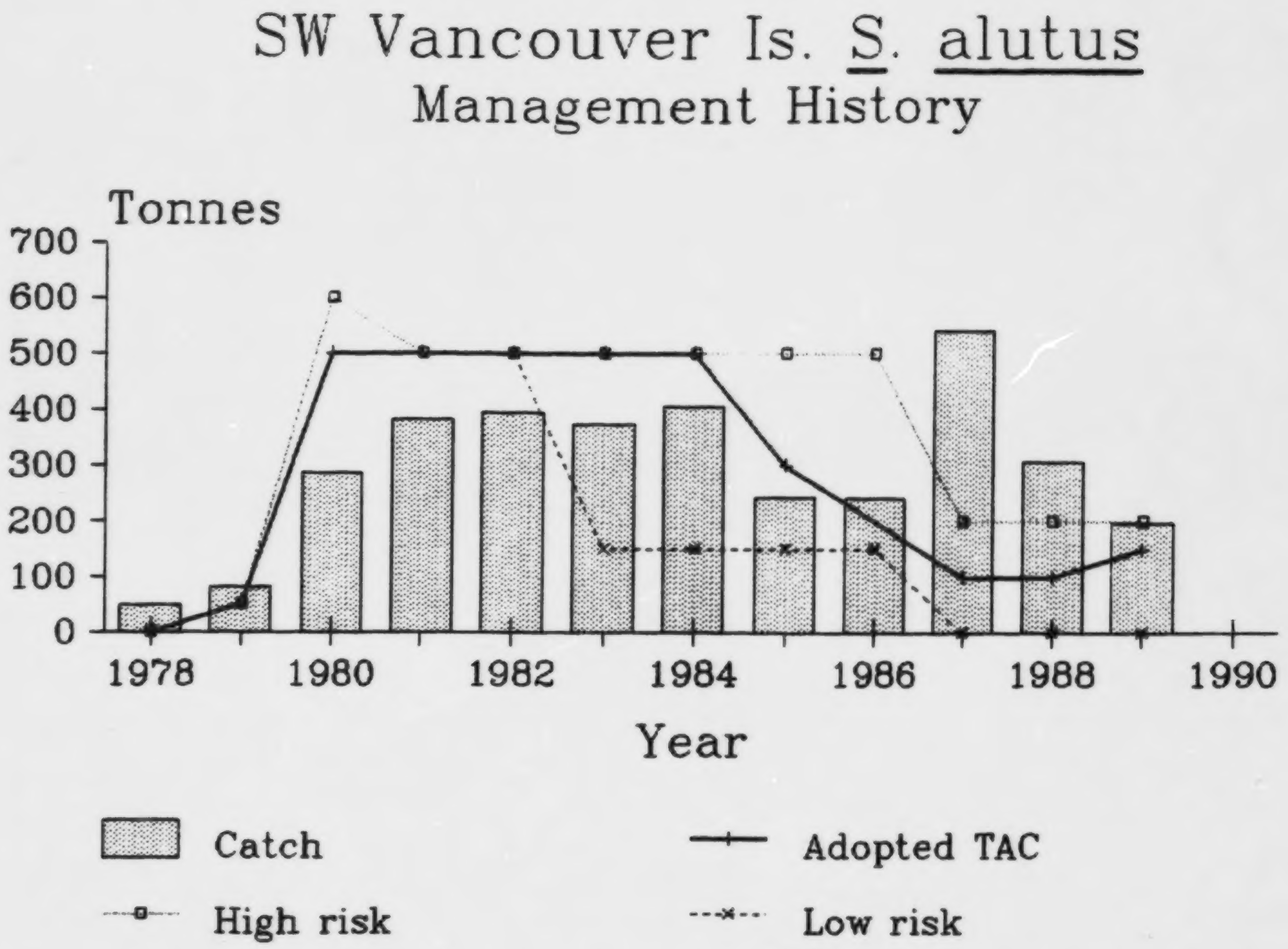


Fig. 9.7. History of stock management for Pacific ocean perch off southwest Vancouver Island, 1978-1989. High risk and low risk figures are recommended yield options.

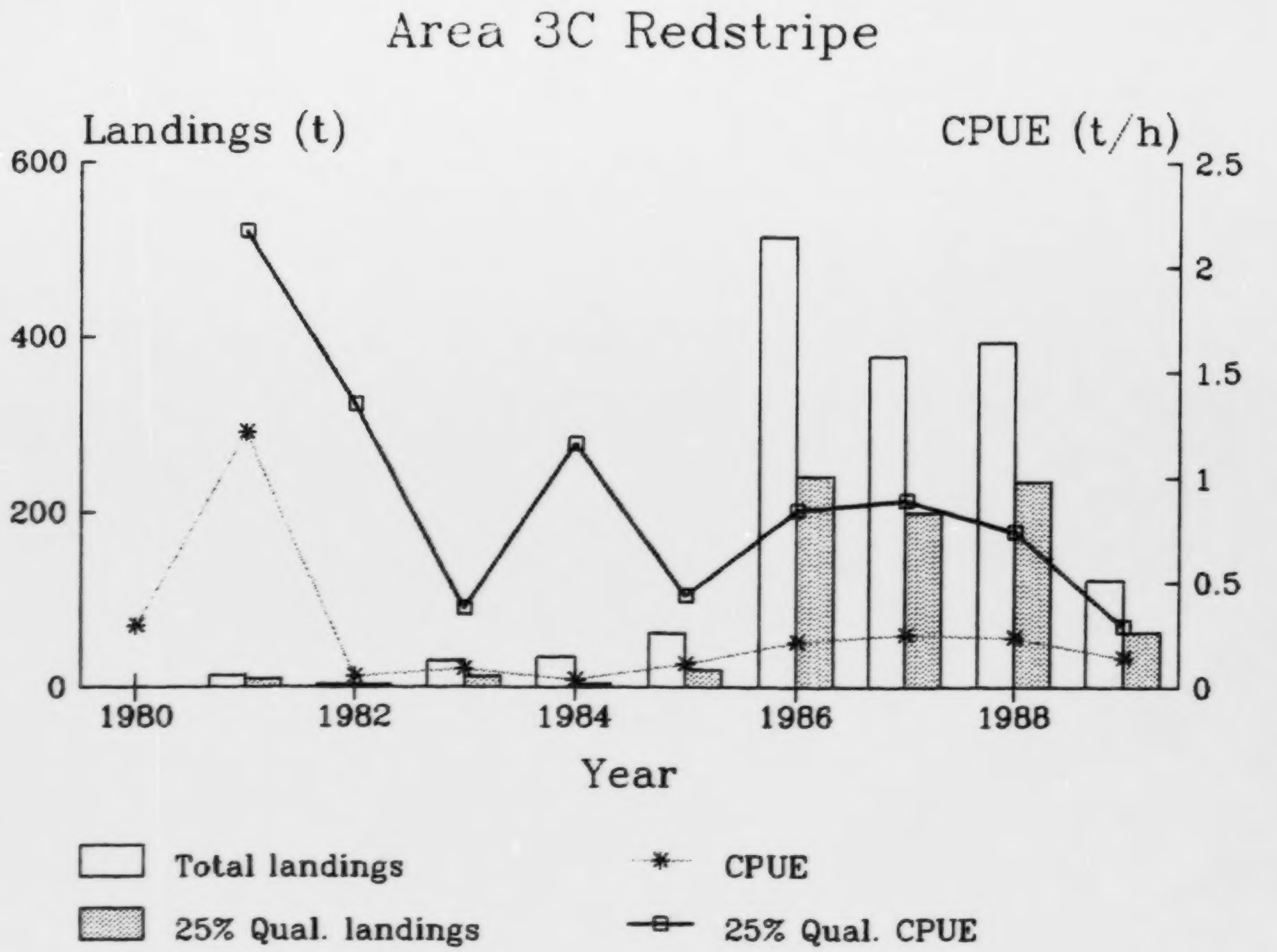


Fig. 9.8. Catch and catch per unit effort (CPUE) for redstripe rockfish (Sebastes proriger) off southwest Vancouver Island (Area 3C + Area 125), 1978-1939. Qualified statistics include data where ≥ 25% of catch was redstripe rockfish.

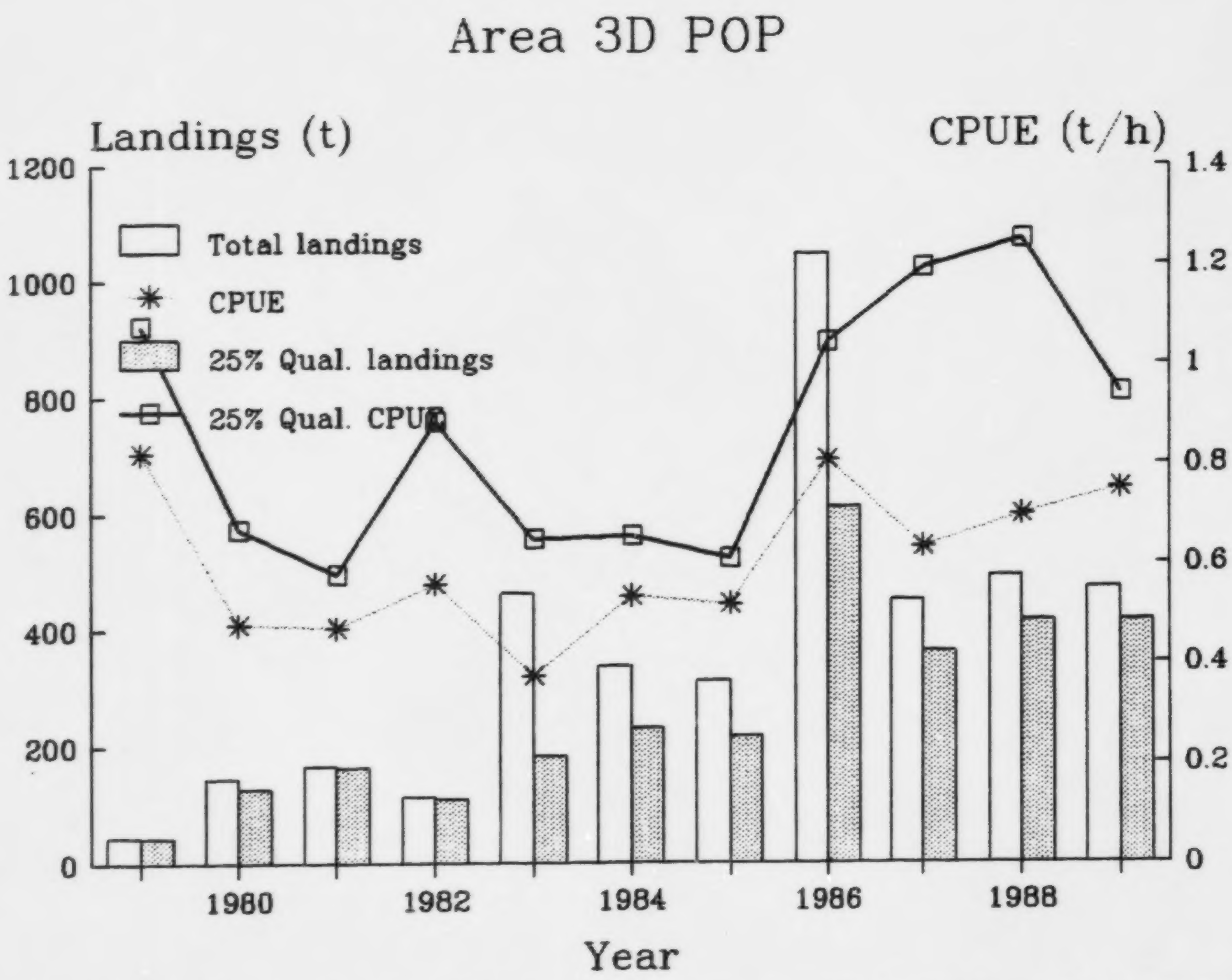


Fig. 9.9. Catch and catch per unit effort (CPUE) for Pacific ocean perch (S. alutus, POP) off northwest Vancouver Island (Area 3D), 1979-1939. Qualified statistics include data where ≥ 25% of catch was POP.

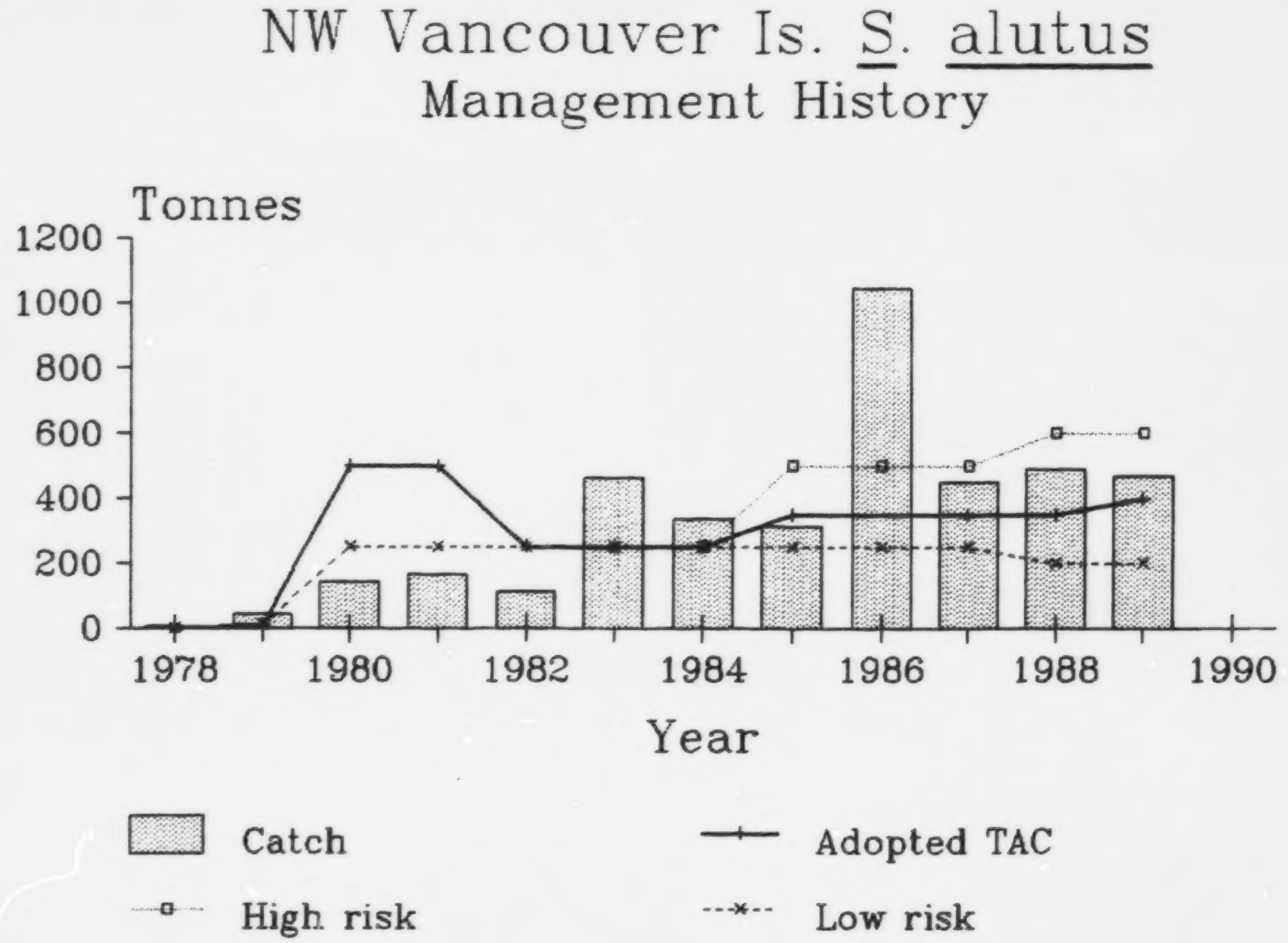


Fig. 9.10. History of stock management for Pacific ocean perch off northwest Vancouver Island, 1978-1989. High risk and low risk figures are recommended yield options.

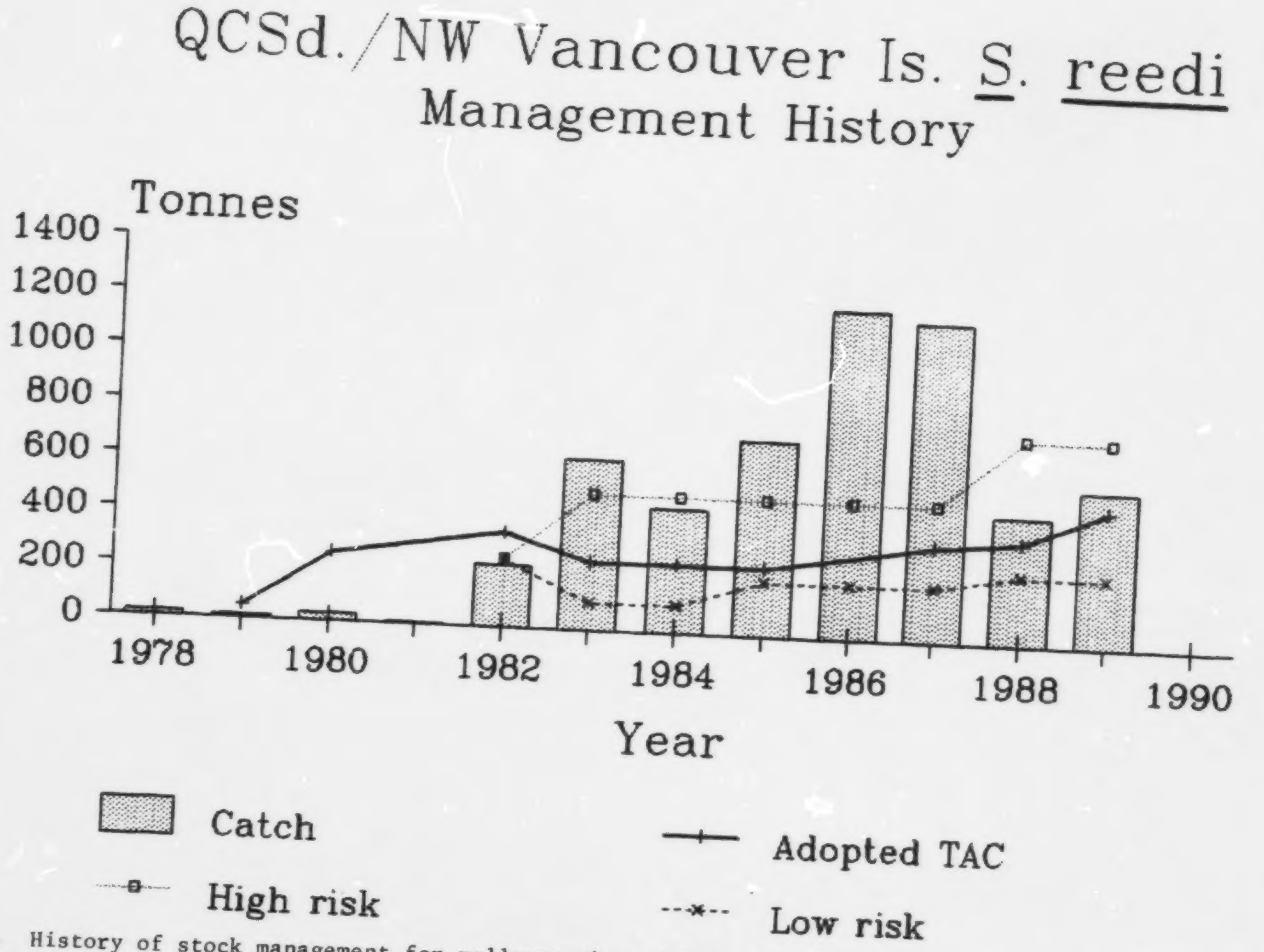


Fig. 9.11. History of stock management for yellowmouth rockfish off northwest Vancouver Island-southern Queen Charlotte Sound, 1978-1989. High risk and low risk figures are recommended yield options.

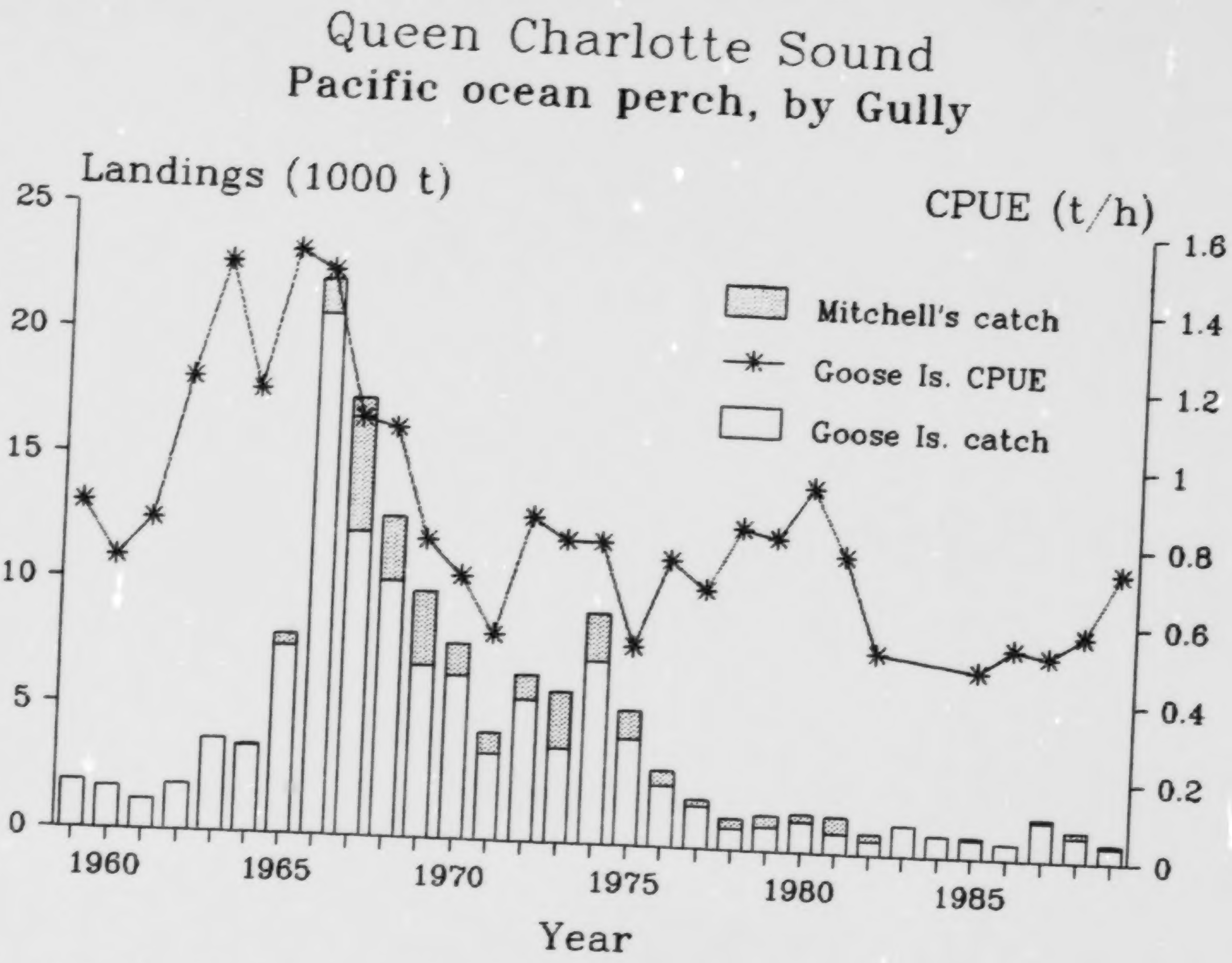


Fig. 9.12. Catch and catch per unit effort (CPUE) for Pacific ocean perch (*S. alutus*, POP) in Queen Charlotte Sound, 1959-1989, by gully. 1933-1934 winter fishery on spawning females excluded.

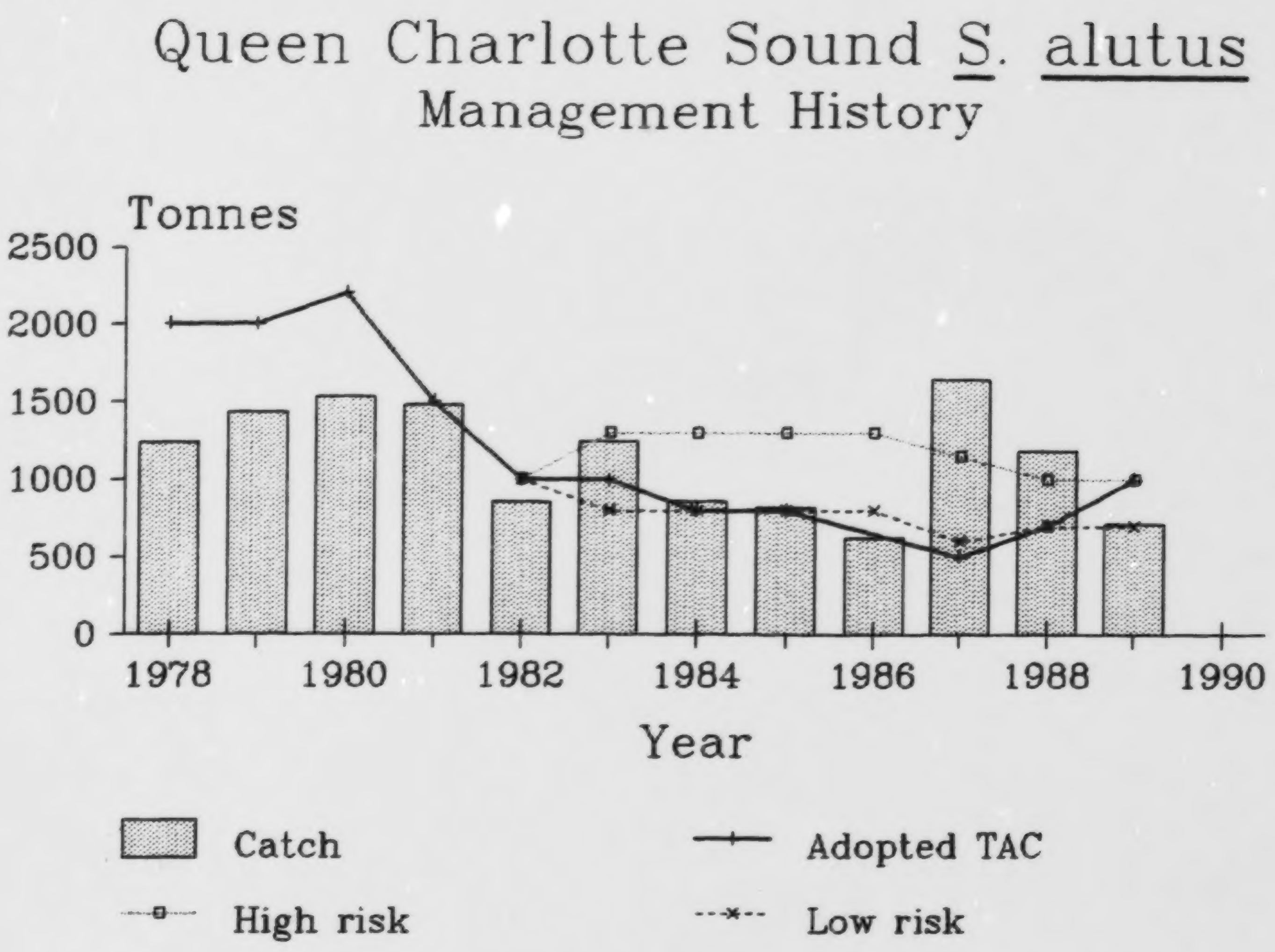


Fig. 9.13. History of stock management for Pacific ocean perch in Queen Charlotte Sound, 1978-1989. High risk and low risk figures are recommended yield options.

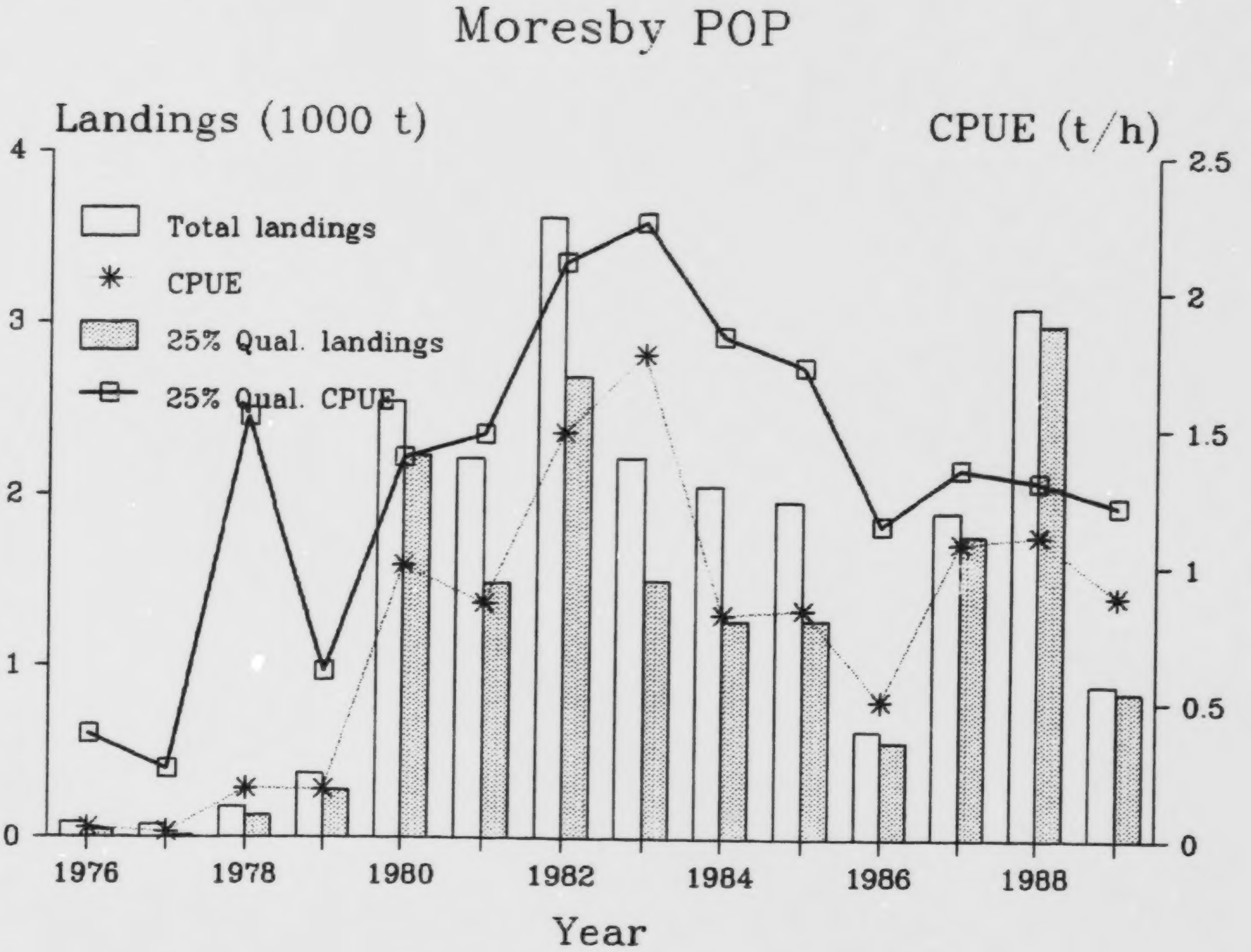


Fig. 9.14. Catch and catch per unit effort (CPUE) for Pacific ocean perch (*S. alutus*, POP) in Moresby Gully, 1976-1989. Qualified statistics include data where ≥25% of catch was POP.

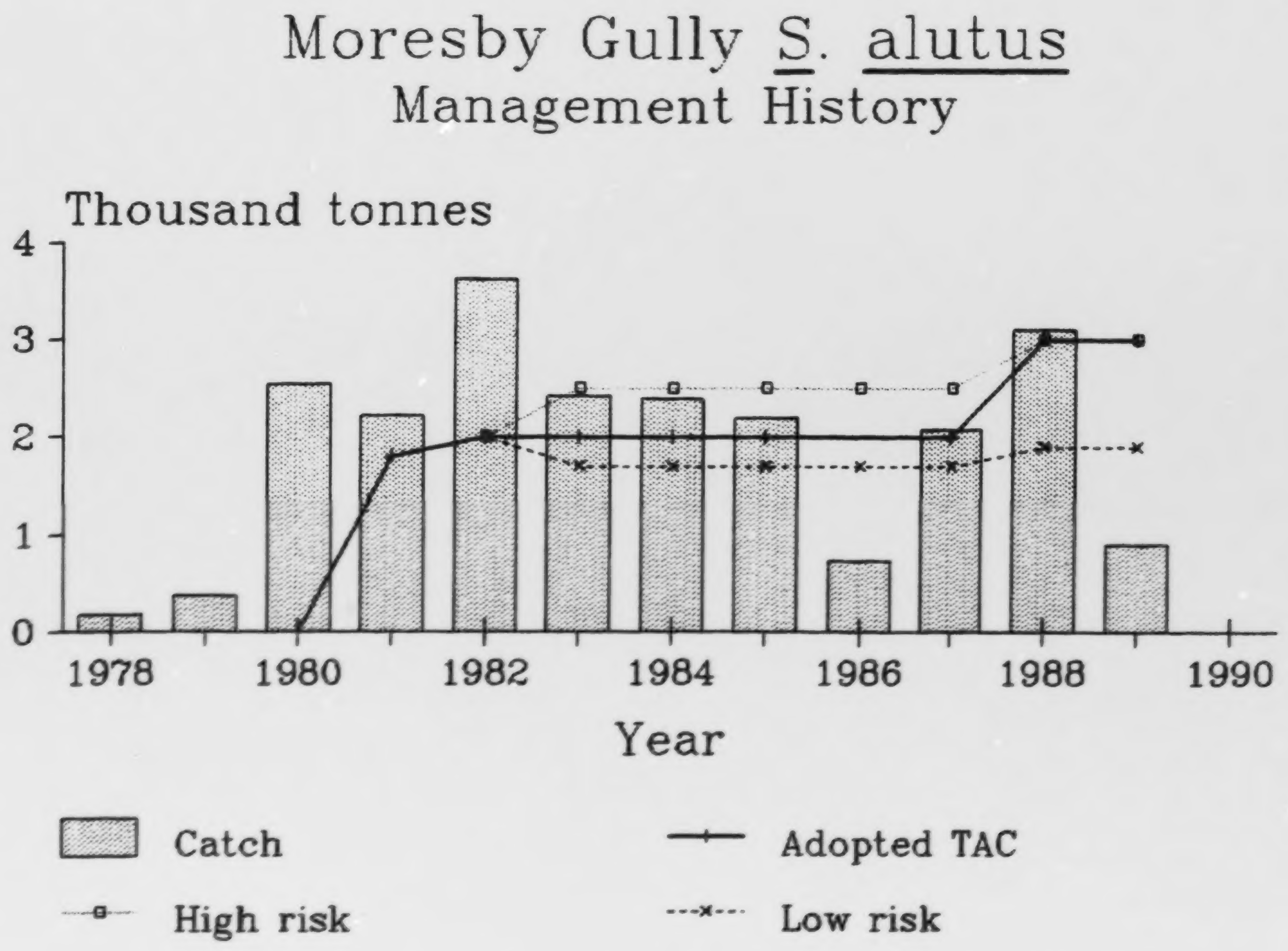


Fig. 9.15. History of stock management for Pacific ocean perch in Moresby Gully, 1978-1939. High risk and low risk figures are recommended yield options.

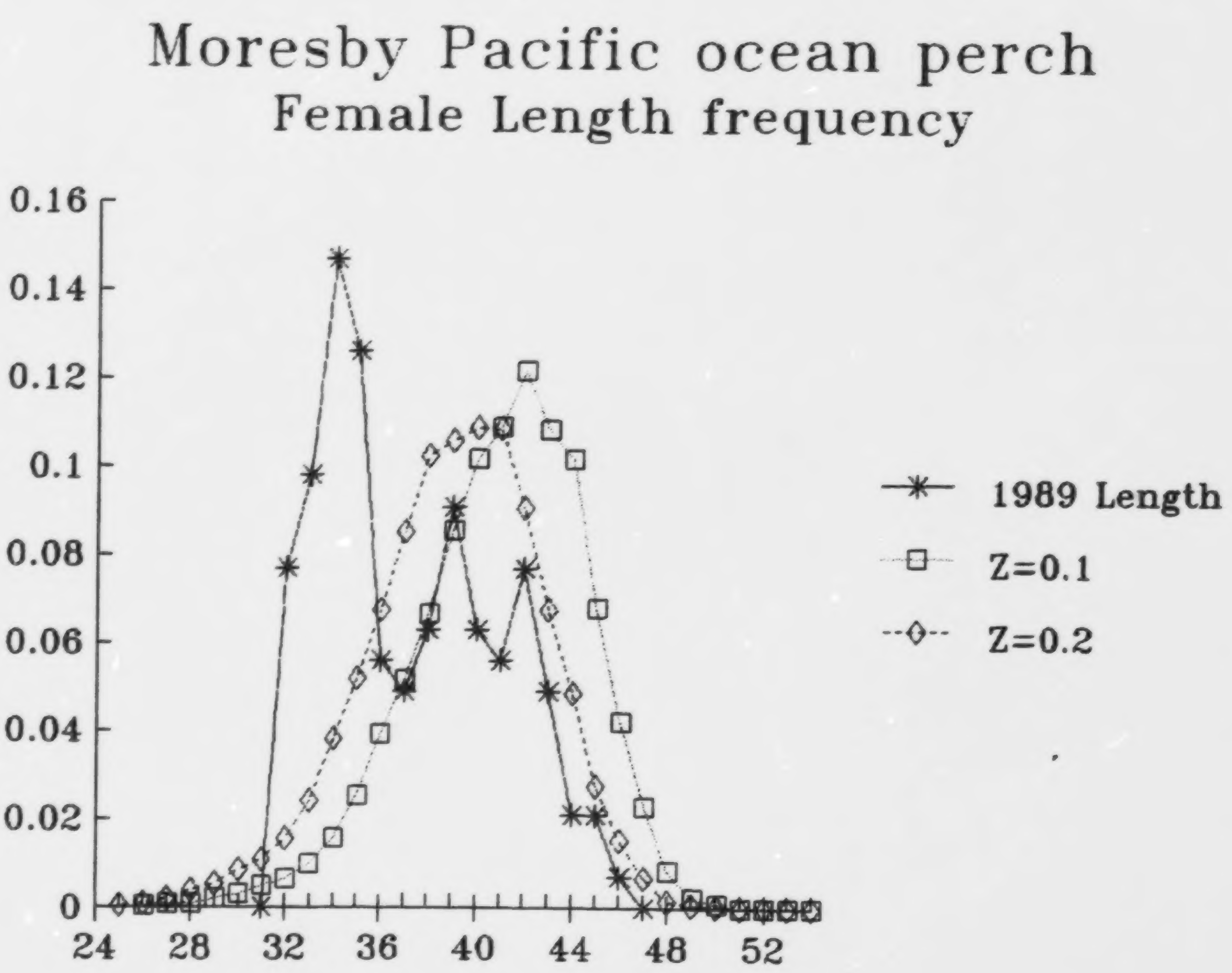


Fig. 9.16. Length frequency of female Pacific ocean perch (S. alutus, POP) from Moresby Gully in 1939, compared with the frequencies generated using known mortality rates (Z=0.1, 0.2).

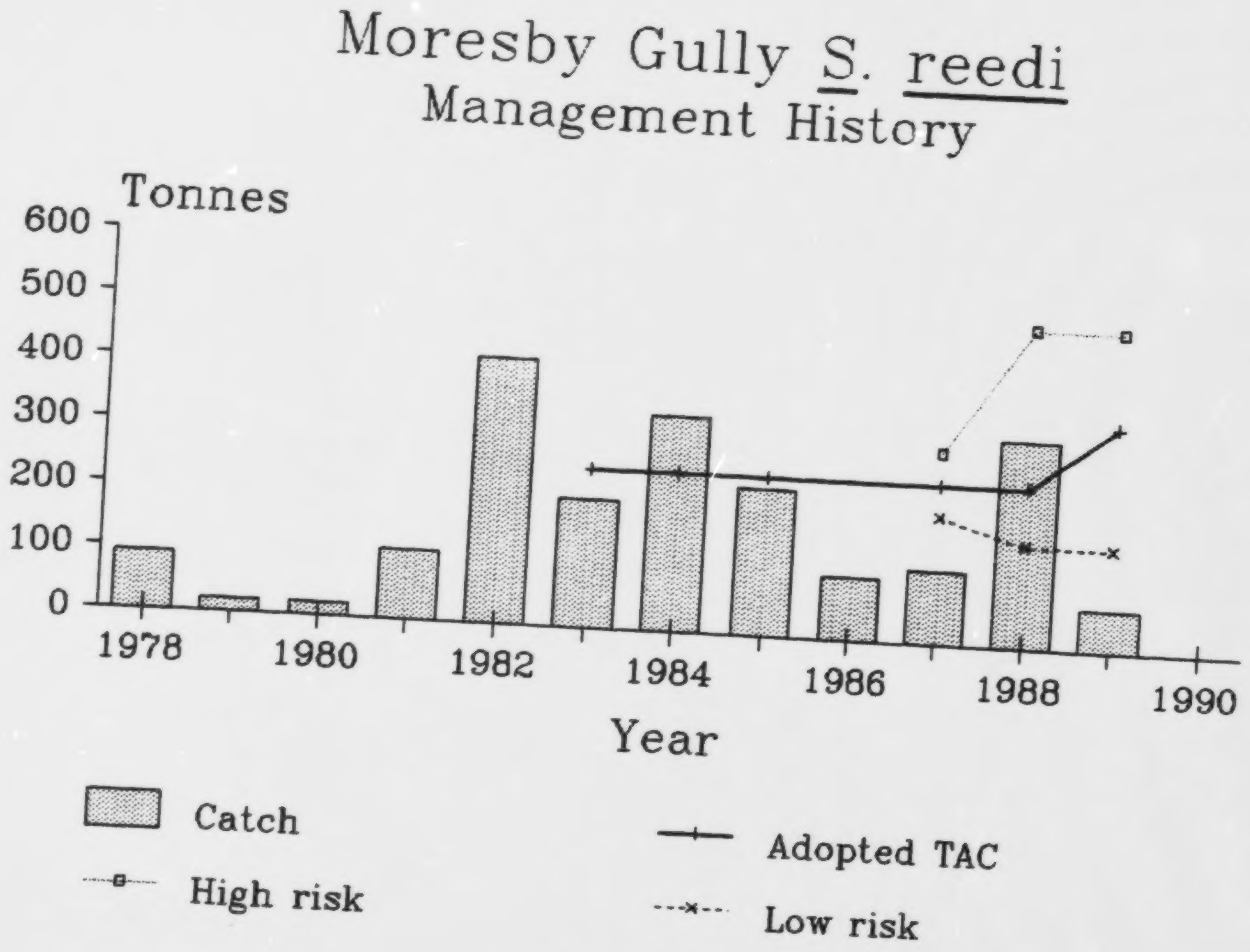


Fig. 9.17. History of stock management for yellowmouth rockfish in Moresby Gully, 1978-1989. High risk and low risk figures are recommended yield options.

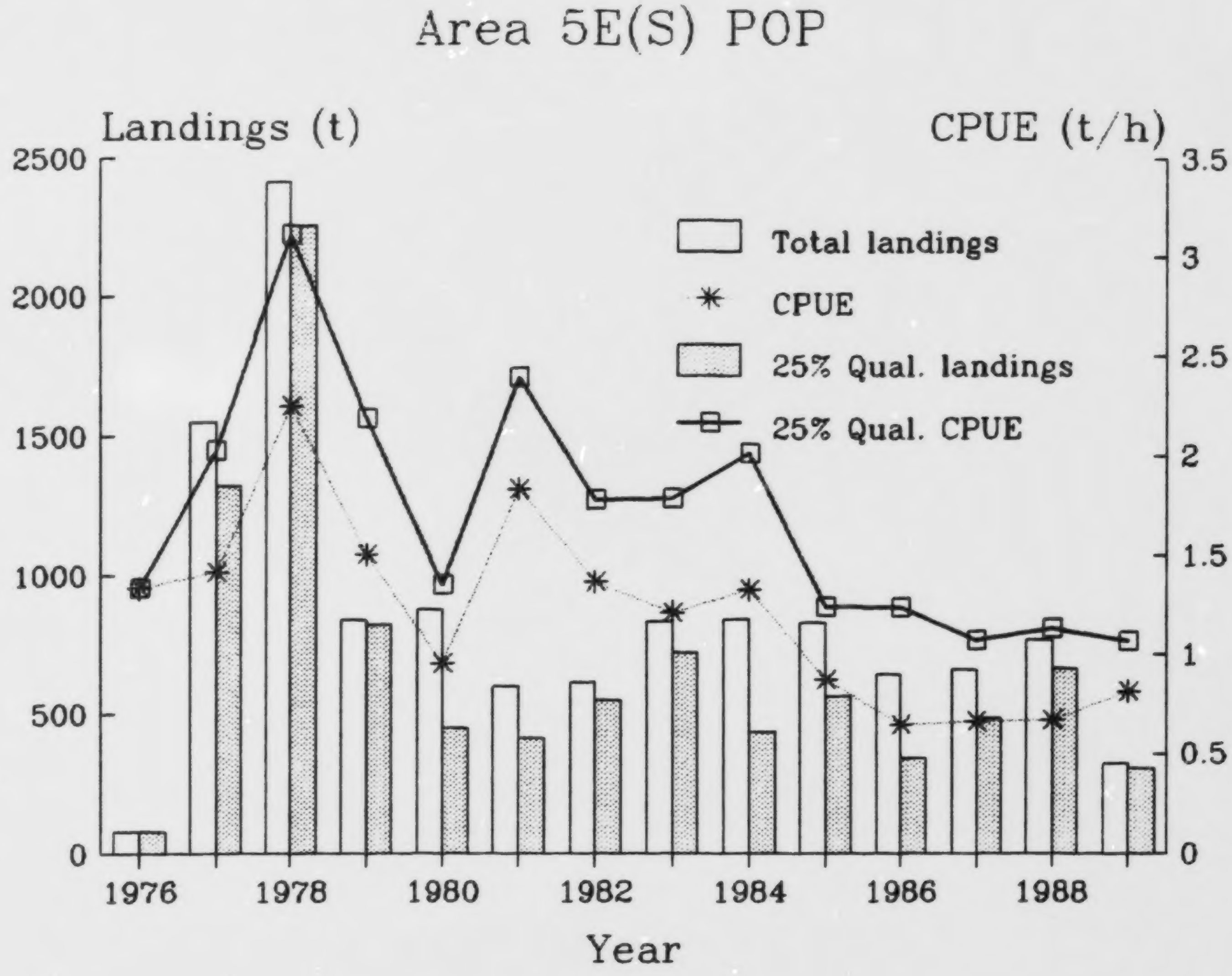


Fig. 9.18. Catch and catch per unit effort (CPUE) for Pacific ocean perch (*S. alutus*, POP) off the west coast of the Queen Charlotte Islands (Area 5E(S)), 1976-1989. Qualified statistics include data where ≥ 25% of catch was POP.

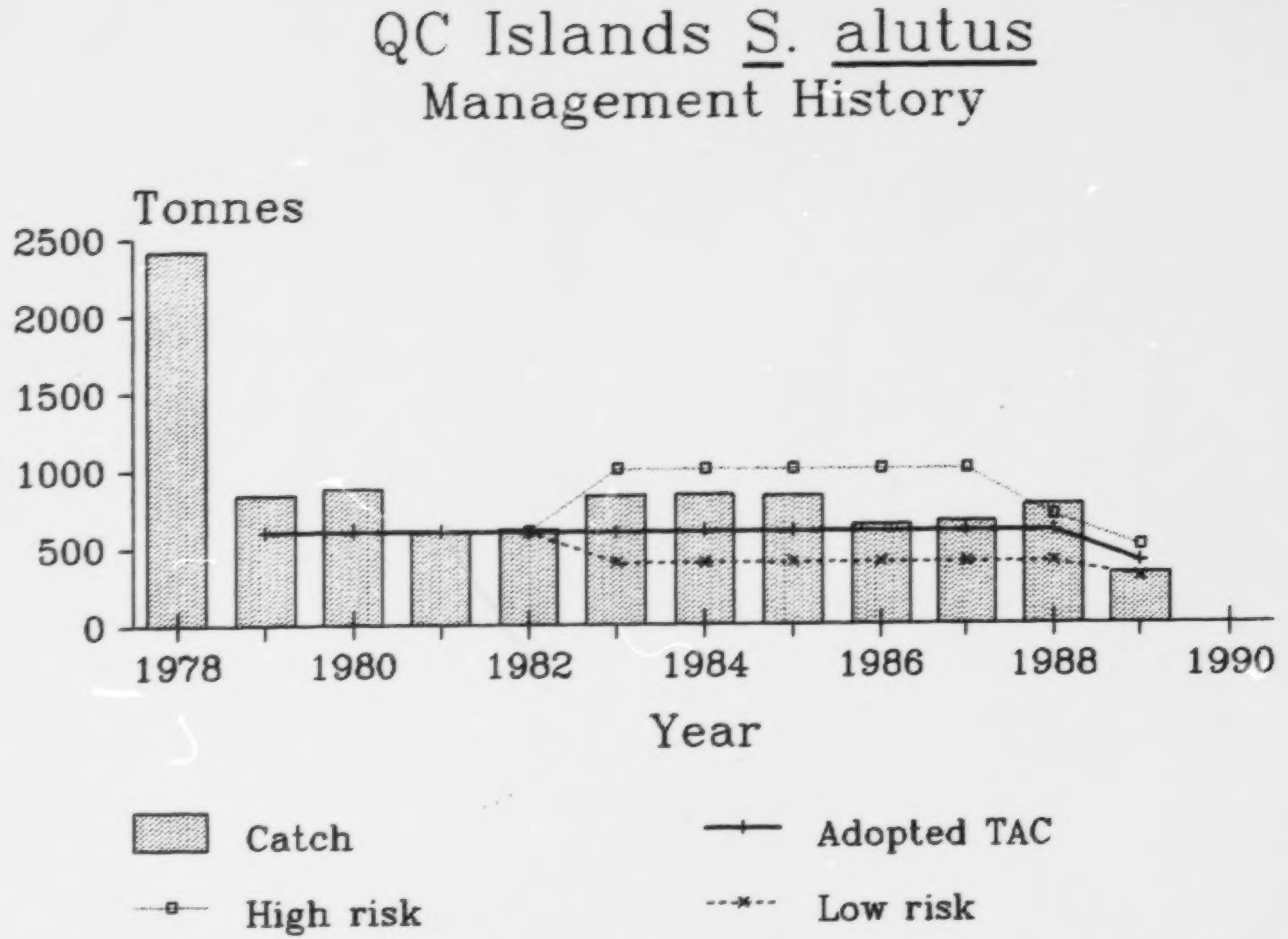
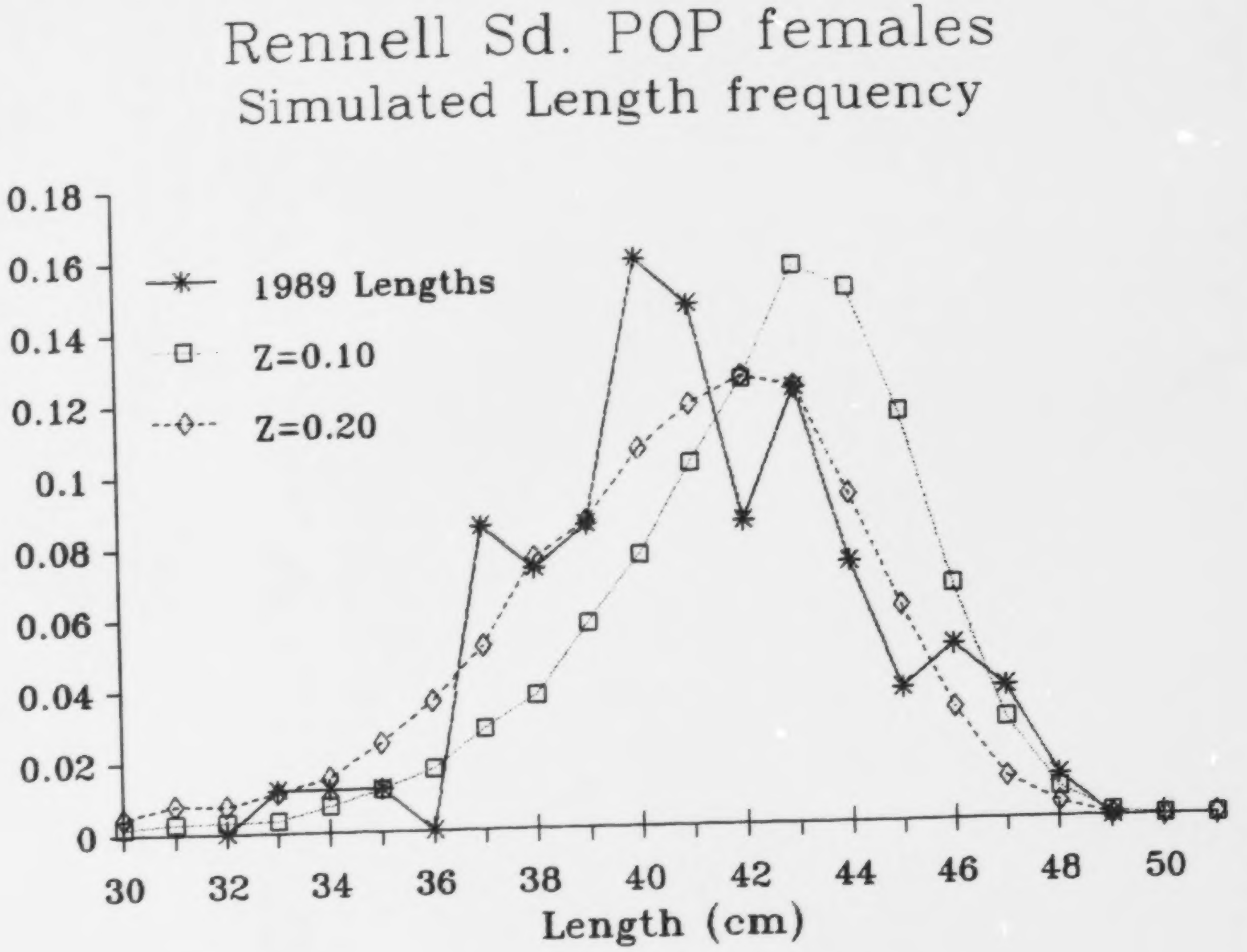


Fig. 9.19. History of stock management for Pacific ocean perch off the west coast of the Queen Charlotte Islands, 1978-1989. High risk and low risk figures are recommended yield options.



Fig, 9.20. Length frequency of female Pacific ocean perch (S. alutus, POP) from Rennell Sound (Area 5E (S)) in 1989, compared with the frequencies generated using known mortality rates (Z=0.1, 0.2).

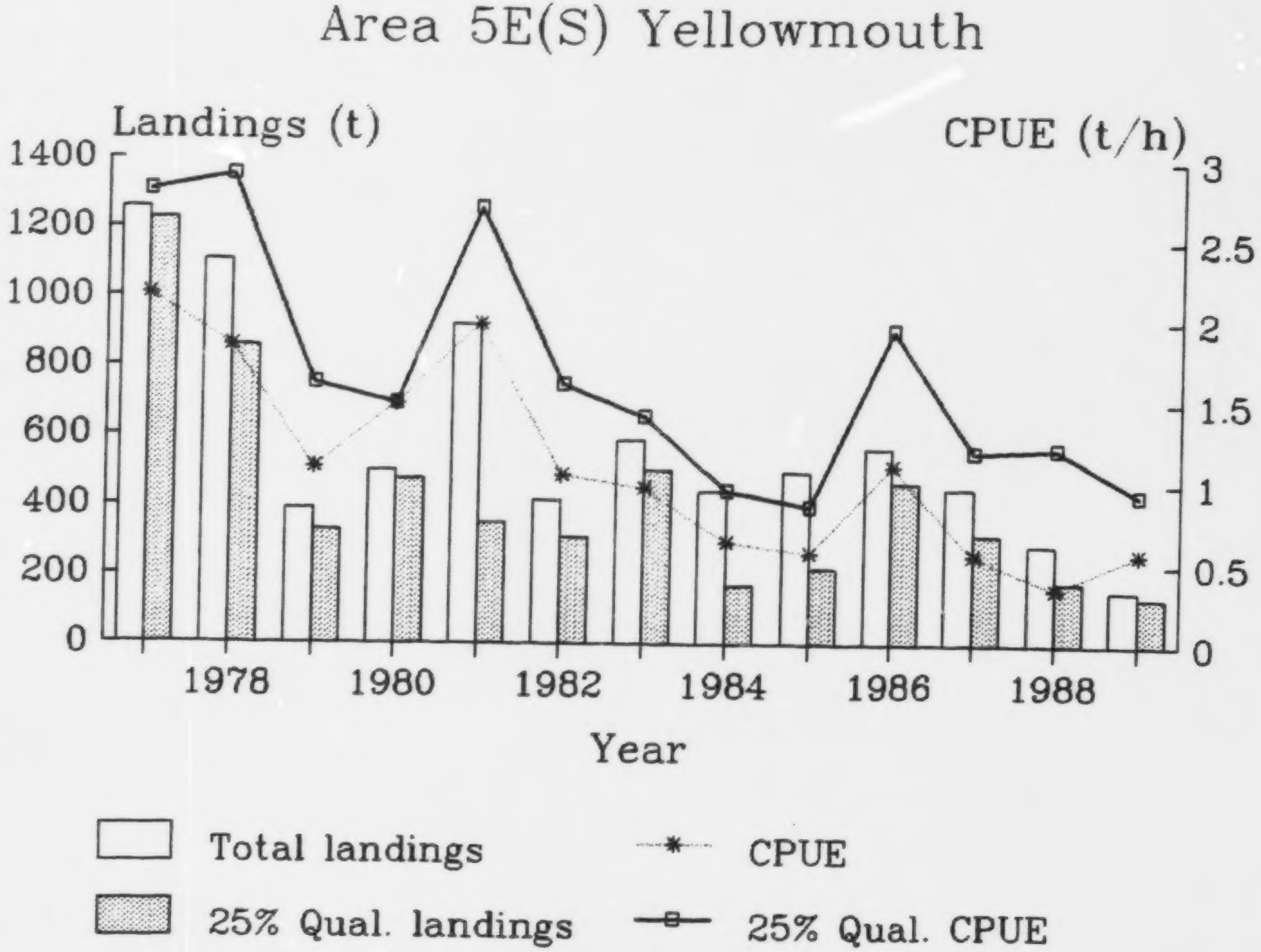


Fig. 9.21. Catch and catch per unit effort (CPUE) for yellowmouth rockfish (S. reedi) off the southwest coast of the Queen Charlotte Islands (Area 5E(S)), 1977-1989. Qualified statistics include data where ≥ 25% of catch was yellowmouth rockfish.

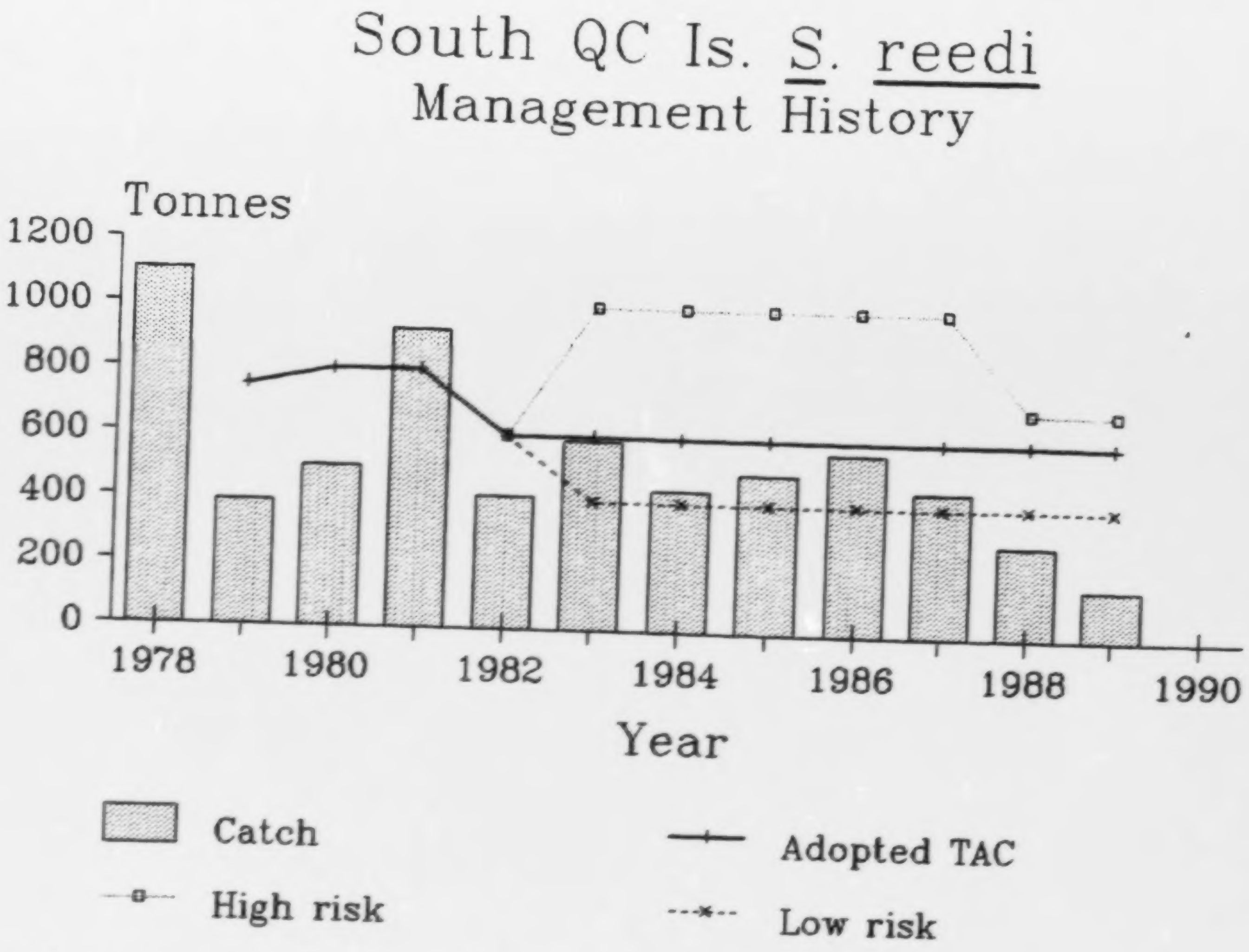


Fig. 9.22. History of stock management for yellowmouth rockfish off the west coast of the Queen Charlotte Islands, 1978-1989. High risk and low risk figures are recommended yield options.

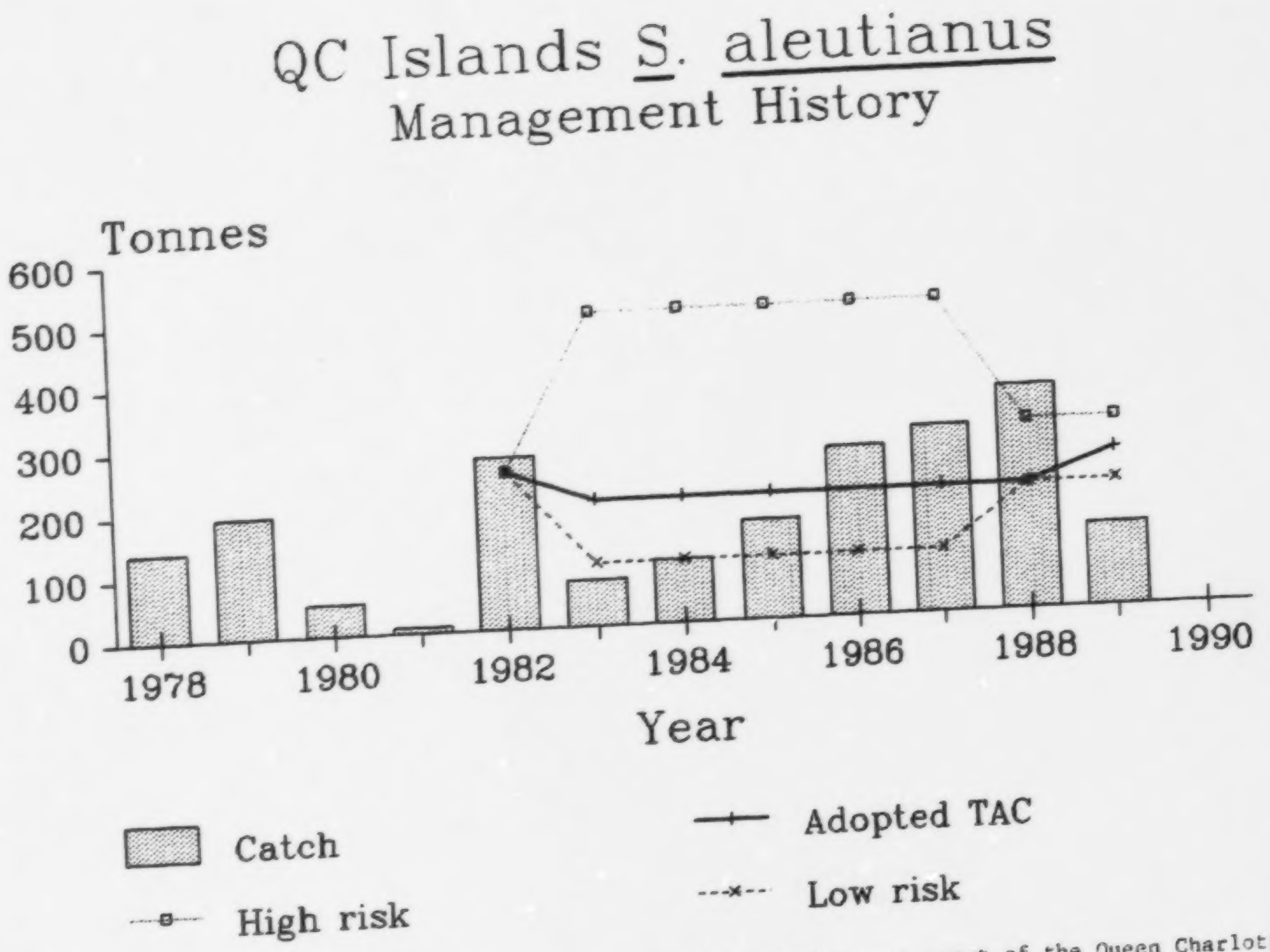


Fig. 9.23. History of stock management for rougheye rockfish off the west coast of the Queen Charlotte Islands, 1978-1989. High risk and low risk figures are recommended yield options.

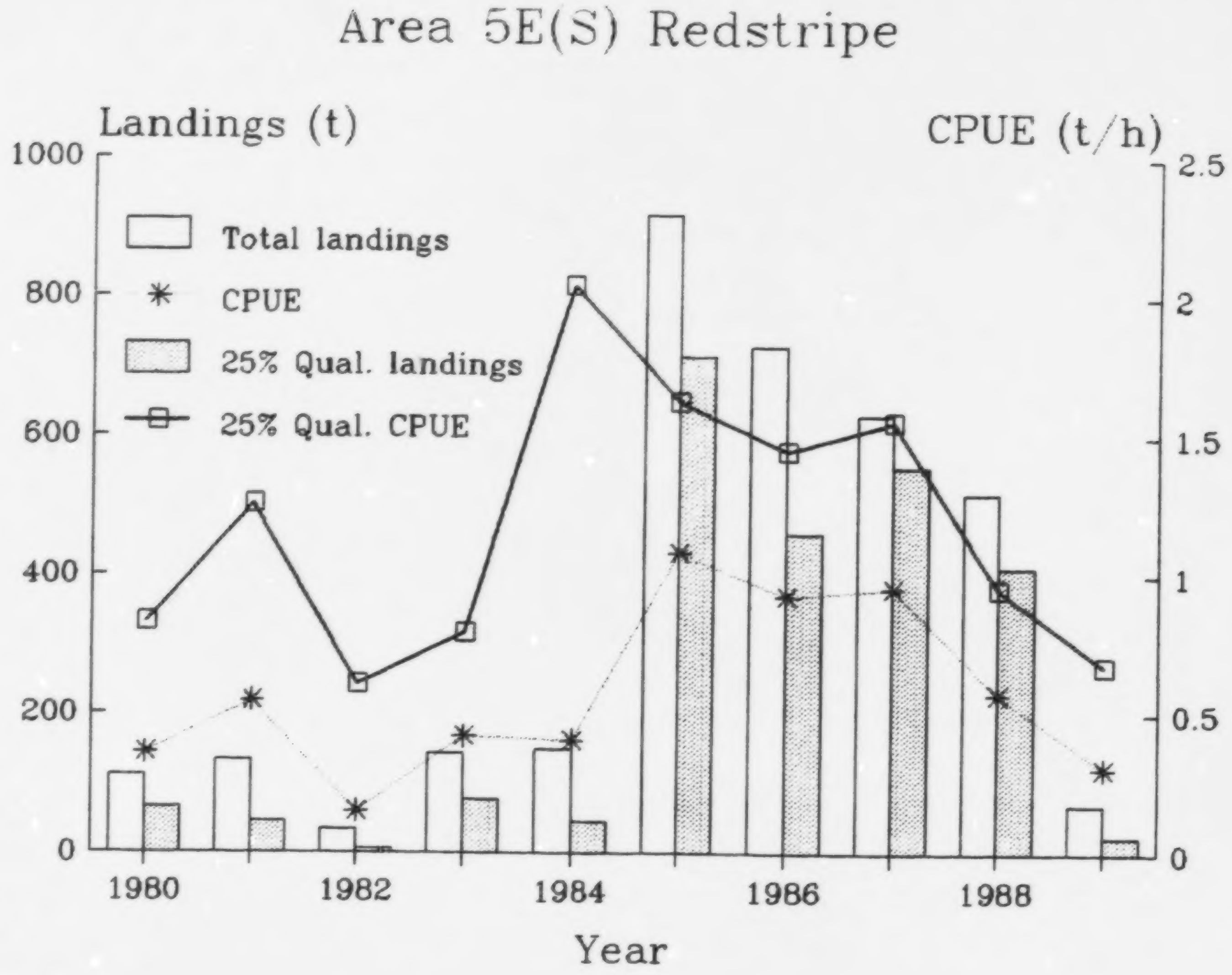


Fig. 9.24. Catch and catch per unit effort (CPUE) for redstripe rockfish (S. proriger) off the southwest coast of the Queen Charlotte Islands (Area 5E(S)), 1980-1989. Qualified statistics include data where ≥ 25% of catch was redstripe rockfish.

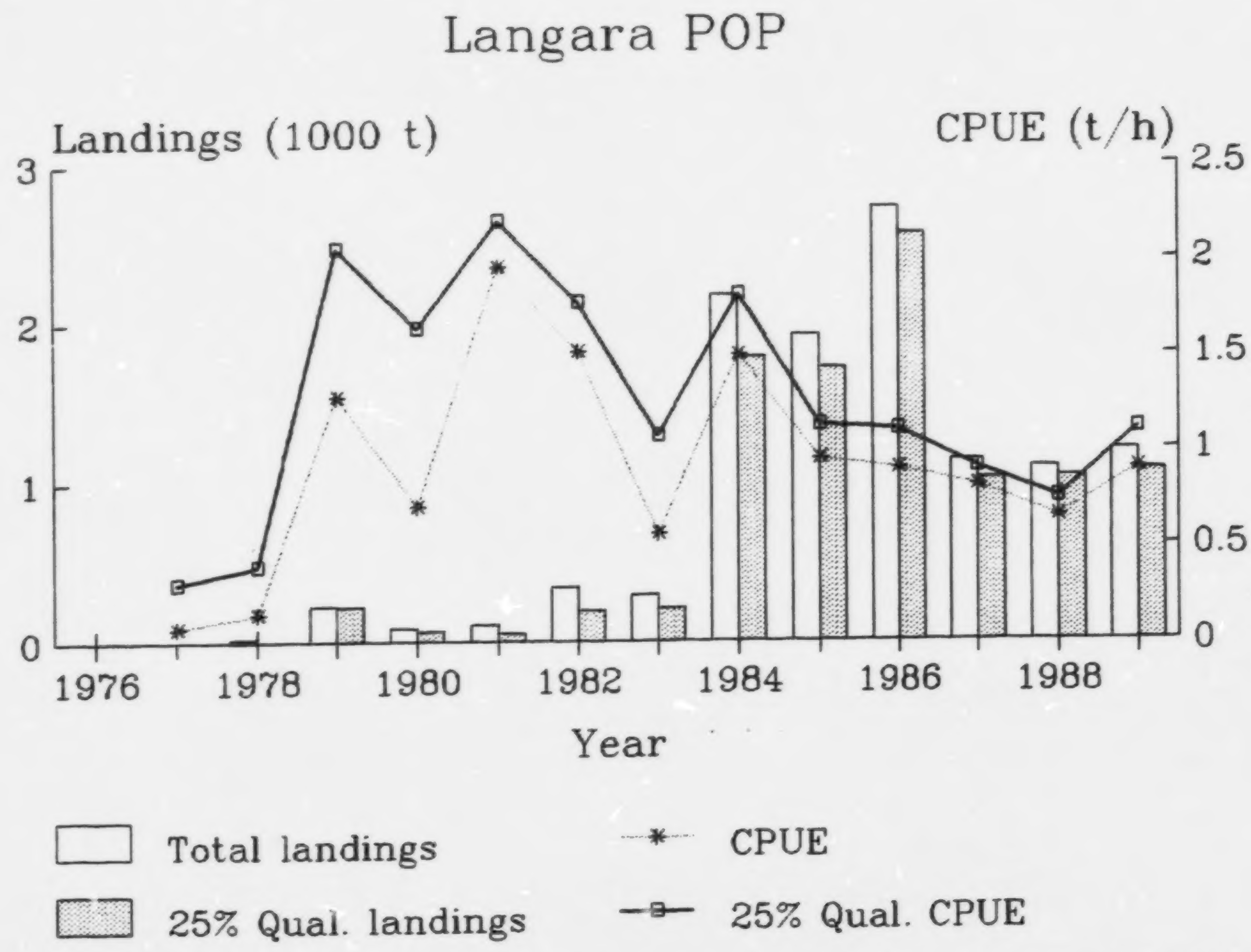


Fig. 9.25. Catch and catch per unit effort (CPUE) for Pacific ocean perch (S. alutus, POP) in Area 5E (N) (Langara Spit), 1976-1989. Qualified statistics include data where ≥ 25% of catch was POP.

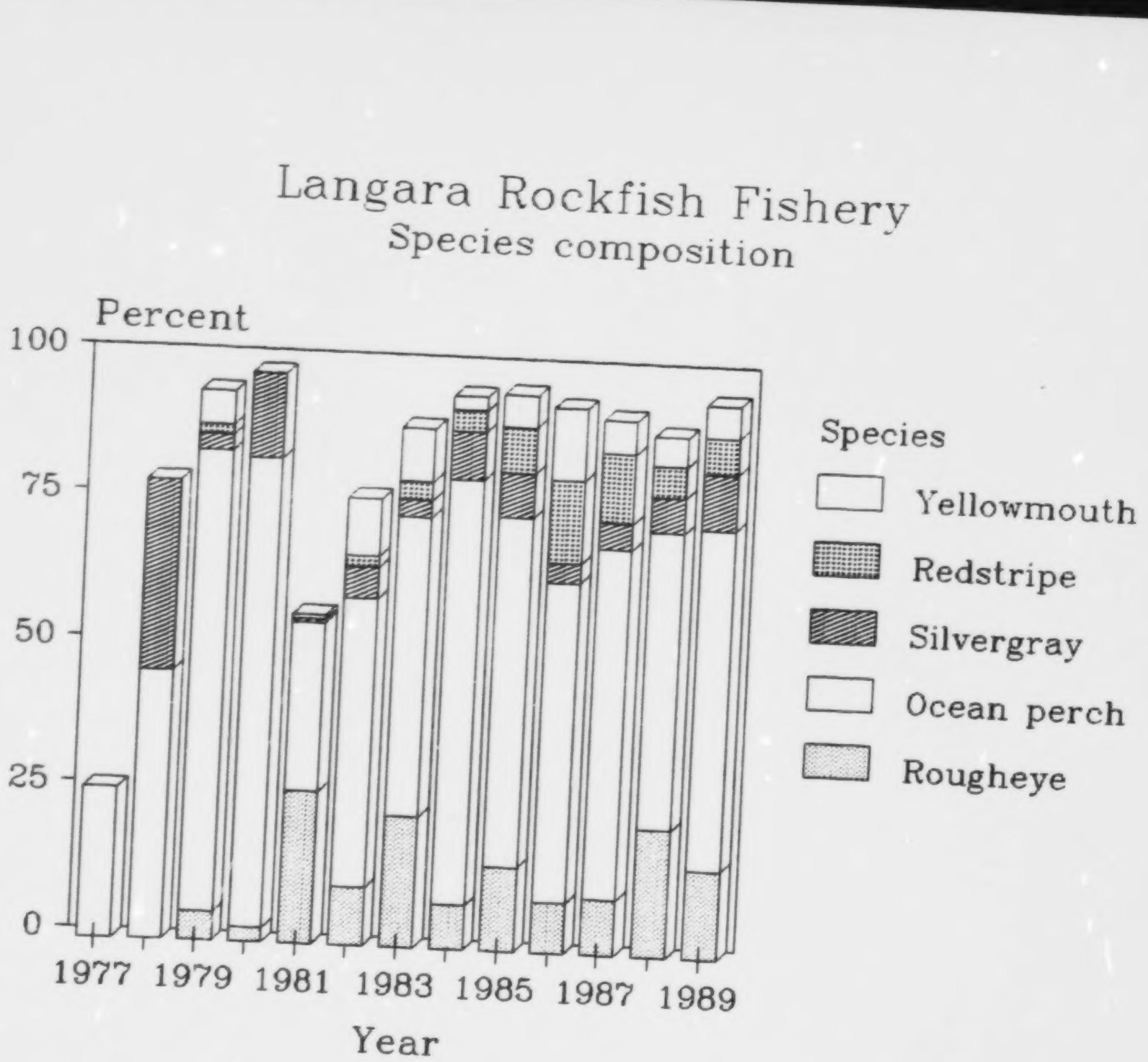


Fig. 9.26. Composition of rockfish catches in the Area 5E(N) (Langara Spit) fishery, by major species, 1977-1989.

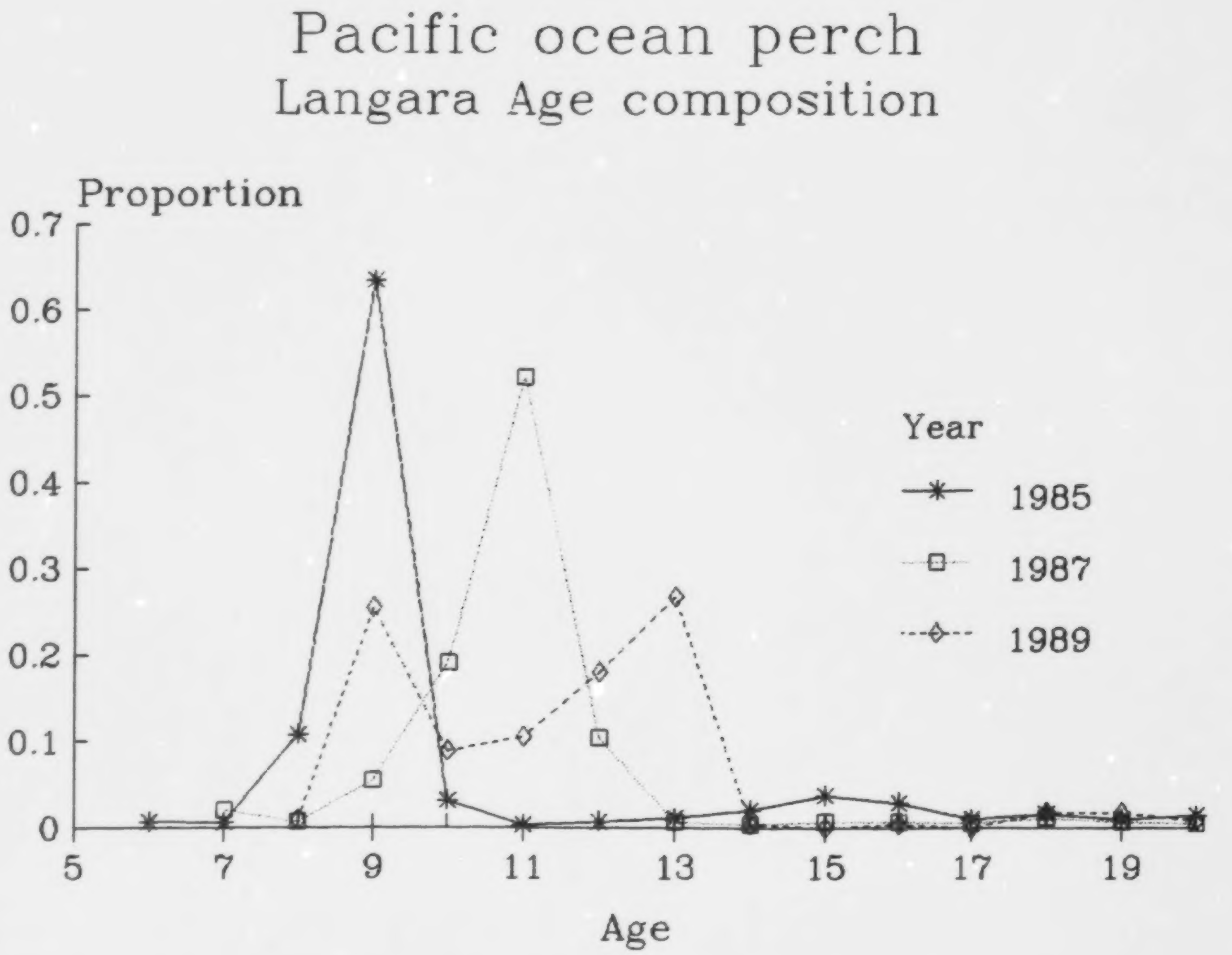


Fig. 9.27. Age composition of the Pacific ocean perch (*S. alutus*) stock from Langara Spit, 1985-1937. The dominant year-class in each year is the 1976 year-class.

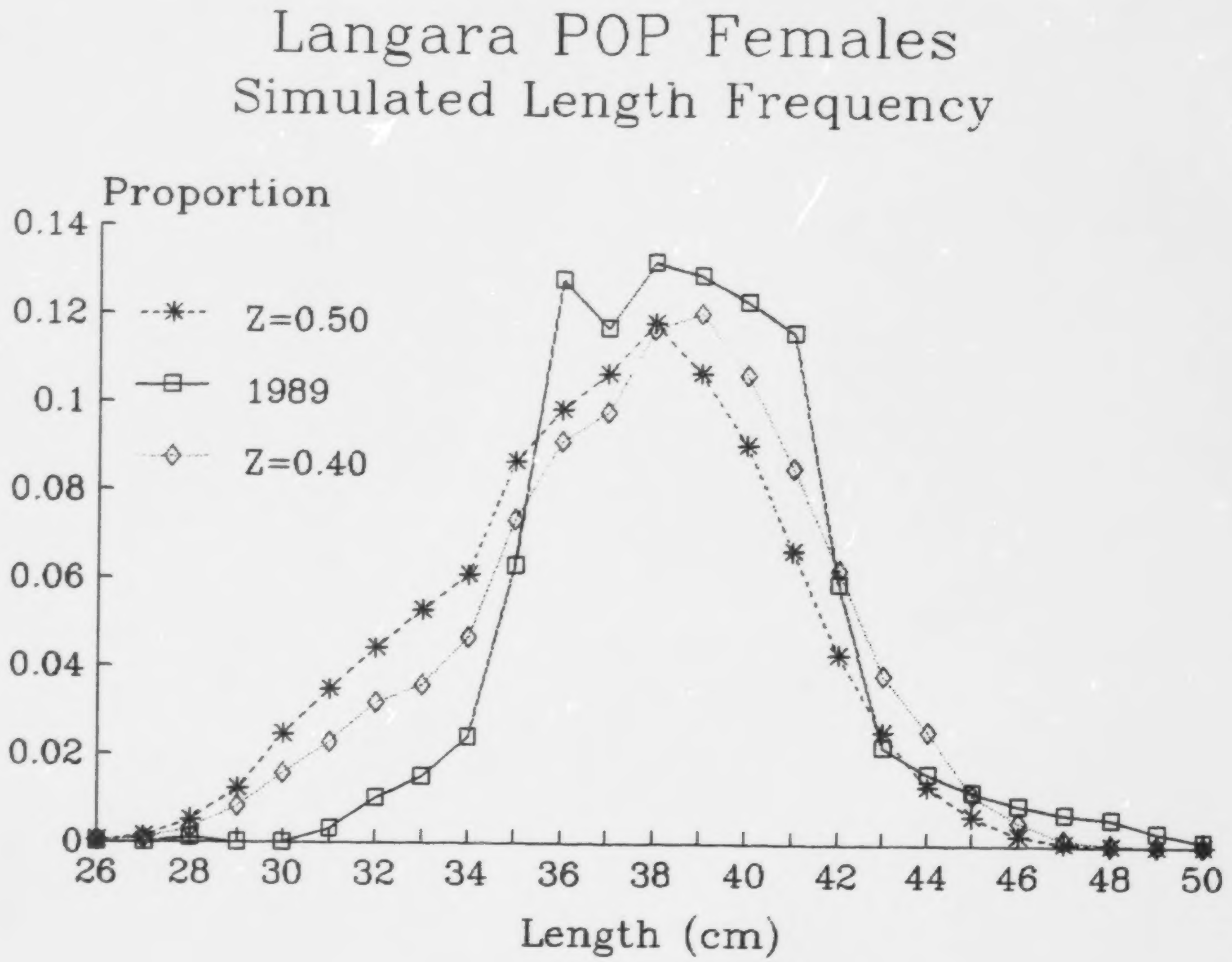


Fig. 9.28. Length frequency of female Pacific ocean perch (S. alutus, POP) from Langara Spit (Area 5E (N)) in 1989, compared with the frequencies generated using known mortality rates (Z=0.4, 0.5).

10.0. SHELF ROCKFISH (silvergray, yellowtail and canary rockfish)

by R. D. Stanley

10.0.1. General Introduction

The time series of age data are too short or incomplete to conduct catch-at-age analyses for the silvergray and canary rockfish stocks. As in previous documents, information on catch rates and current size is evaluated to assess the impact of the average level of past harvests (Leaman and Stanley 1985, Stanley 1987a, Stanley 1987b, Stanley 1989). The B.C. yellowtail rockfish fishery is examined for the first time with catch-at-age analysis.

We recommend a yield range for each stock (Table 10.1). The lower limit is a conservative estimate of sustainable yield. Yields above the upper limit are unlikely to be sustainable. While total landings for these three species of shelf rockfish reached approximately 10,000 t for the first time in 1988 (Figure 10.1), we have lowered our recommended ranges for three of the five traditional fisheries for canary and silvergray rockfish. The recommendations for yellowtail rockfish remain approximately the same.

We explained in the previous document (Stanley 1989) how we estimate standardized catch rates and included examples of the variance about the estimates. The time series are re-standardized each year which accounts for the minor changes to the time series if current figures are compared with previous reviews. Nominal (unstandardized) catch rates are shown with the landings data.

10.1. Coastwide

10.1.1. Silvergray and Canary Rockfish

We have not presented coastwide options for silvergray or canary rockfish.

10.1.2. Yellowtail Rockfish

10.1.2.1. Introduction

Yellowtail rockfish have recently become a significant trans-boundary concern because of the increase in landings by Canadian trawlers fishing on the "Nootka" grounds off the central west coast of Vancouver Island (Table 10.2). U.S. biologists had treated yellowtail rockfish from northern Washington and southern B.C. (including Nootka) as one stock (INPFC-Vancouver Area). Based on the historical distribution of landings, they assumed an 80/20 split of the yellowtail biomass between the U.S. and

Canadian zones of the Vancouver Area. Because of the small Canadian landings, U.S. managers were satisfied to manage the stock solely through controls on the U.S. fishery. Canadian biologists assumed that landings from U.S. waters had no significant impact on the population of yellowtail rockfish exploited in Canadian waters as the Canadian fishery had always been concentrated to the north in Queen Charlotte Sound (INPFC-Charlotte Area).

Starting in 1986, however, Canadian landings from the Nootka area increased significantly to be equivalent to the U.S. estimate of sustainable yield for the whole Vancouver Area (Tagart 1988). While it was not known whether this fishery was exploiting the same population as the U.S. fishery to the south, U.S. biologists perceived that the combined landings represented excessive exploitation of a unit stock.

At the 1988 Annual Meeting of the Canada/U.S. Groundfish Committee, the Technical Subcommittee recommended that a Yellowtail Rockfish Working Group be appointed. They stated that this Working Group should:

1. Review the status of the yellowtail rockfish stocks;
2. Study management strategies for yellowtail rockfish;
3. Review the implications of the various management strategies on the yellowtail rockfish stock;
4. Report to the TSC and Parent Committee on their progress.

The first meeting of the Working Group decided that prior to the development of new analyses and management strategies, the available biological and fishery information would have to be assembled, edited and standardized. The second step would be to examine stock delineation with the master data set and, based on these conclusions, the third step would be to conduct stock assessments and examine various management strategies. Concurrent with these projects, the Working Group would initiate specific biological studies to improve the information base for the assessments.

In addition to these international considerations, the fishery has gained prominence in the Canadian domestic fishery as total landings from B.C. waters have increased from less than 1000 t per year during 1980-1984 to approximately 5000 t from 1986-1988 (Table 10.2). Yellowtail rockfish quotas (which were not attained 5-10 years ago) are now a source of contention with Industry.

10.1.2.2. Landing Statistics

The Canadian domestic fishery landed 4766 t of yellowtail rockfish in 1988. The offshore hake fishery captured an additional 334 t (Mark Saunders, unpublished data). The ratio of yellowtail rockfish to hake was 0.0023 in joint-venture catches and 0.0102 in the National fisheries. Davenport (1985) had previously estimated the two ratios as 0.0015 and 0.0228 respectively in the 1983 fishery.

Our estimates of bycatch for 1977-85 are based on the 1983 ratios. The 1986 and 1987 bycatch estimates are now based on the ratios observed in 1988. The 1989 bycatch is projected from the 1988 bycatch ratios and projected hake catches of 62,500 t by joint-venture and 21,000 t by national fisheries (B. Ackerman, pers. comm). The average yield from B.C. waters, 1967-1987, was 2450 t.

Standardized trawl CPUE for Queen Charlotte Sound (Q.C.Sd.), and the west coast of Vancouver Island appears stable (Table 10.3, Figure 10.2) except that midwater trawl CPUE in the latter area declined 50% from the first year to the second year. It has since remained stable at the lower level. CPUE in Q.C.Sd. has remained fairly stable.

10.1.2.3. Stock Delineation

The Working Group has initiated studies on parasites, tissue proteins (electrophoresis), and reproductive biology of yellowtail rockfish to identify meaningful stock boundaries, but these studies are still in progress and preliminary results have been inconclusive.

Some insight into possible stock boundaries was gained from 30 tag recoveries. DFO Canada tagged 14,312 yellowtail rockfish from 1980-1982 off B.C. and northern Washington. Most of the recoveries were recaptured in the same general area of tagging (Figure 10.3). For those fish that moved a significant distance, the trend was southward. However, landings in the mid-1980s were so low in central and northern B.C., that the likelihood of recovering a fish that moved northward would have been very low.

We tested the hypothesis that the population is one homogeneous stock by expressing tag recoveries as a fraction of landings. If the population were fully mixed then the ratio of tagged to untagged fish in landings should have been equal among areas.

We first calculated annual recoveries per ton for the main areas of tag recoveries. This provided a discount rate, since the rate of tag recoveries must be time dependent and two areas would not be comparable unless landings were constant or adjusted (Table 10.4). The ratio of recoveries to landings of Q.C.Sd. tagged fish was 77 times higher for Q.C.Sd. than for southern B.C. and Washington combined. When we restricted the observations to the 1983-1987 period, to give the fish more time to disperse, the ratio was still 44 times higher.

The same ratio was calculated for fish tagged in Area 3C (Canadian and U.S.). The ratio of tags recovered in this combined area of tagging to tags recovered outside the area (3A+2C+2B+2A) was only 4 times as large over the whole time period and 2.5 times as large for 1983-1987. This indicates significant mixing of the populations from the north side of Juan de Fuca canyon in Canadian and U.S. waters with populations to the south, in U.S. waters.

Adult yellowtail rockfish apparently move freely between U.S. grounds in 3C and 3B and the Canadian zone of 3C. There also appears to be significant movement into area 3A, further to the south. However, in spite of long range movement by some individuals, we tentatively conclude that there is not free mixing between Q.C.Sd. and areas off the southwest coast of Vancouver Island and northern Washington (INPFC-Vancouver).

With the stock delineation still unclear for these fisheries, we examined two scenarios for the catch-at-age analysis. The first treated Q.C.Sd. separately from all other fisheries. The second included Q.C.Sd. data with catches and samples from northern B.C. and the recent Nootka fishery. All that is excluded from the latter scenario is the 3C fishery, which from tagging results can be considered part of a population exploited on both sides of the border but not further north.

10.1.2.4. General Biological Information

The catch-at-age database

Compilation of the coastwide yellowtail rockfish database began in the summer of 1988 following the TSC's establishment of the Working Group. The Washington Department of Fisheries (WDF) also aged 3,000 yellowtail rockfish otoliths held in storage by (DFO). These ageing observations provided the basis of the Canadian time series.

Raw data files were screened for obvious errors, and by April 1989 were in suitable condition to be merged into a common database. The database contains 105,363 records (individual fish). It spans 1968-1987 and includes observations from Monterey, California to Q.C.Sd. There are 13,746 records from research cruises and 91,617 from commercial fisheries. The database includes 41,405 break-and-burn ages, 13,184 surface ages, and 8,365 individual weights. Usable ageing data for fish captured in Canadian waters starts in 1975. Some of these early aged samples were WDF port samples taken from U.S. trawlers.

Pooling of samples

Sen (1984) noted that when pooling samples for calculating proportion at age, the sample sizes should be standardized by weight, not by number (i.e., "100 kg" not "200 fish" samples). Standardizing by number can introduce a bias towards overestimating numbers of larger/older fish. Since most rockfish samples were fixed numbers of fish, we removed the bias by calculating total weight of all samples from a length/weight formula (shown below) and standardizing the samples to 1000 kg. The impact on a typical year's estimate of catch-at-age proportions is small but significant (Table 10.5). In one example, proportions at age differed from 0.2-1.2% between the two procedures. The bias will be greater for species where there is more relative contrast in size among the recruited ages.

10.1.2.5. Catch-at-age Analyses

The "Stock Synthesis Model" (SSMOD)

We used the "Stock Synthesis Model" (SSMOD) for analyzing the catch-at-age data (Methot 1989b, c, Methot and Hightower 1989, Hollowed, Babcock, Methot and Dorn 1988). The SSMOD offers the practical advantage of being able to use virtually any form of auxiliary data including length composition data, scale or surface ageing, and effort or survey observations. It permits separate analysis by sex, a necessity for yellowtail rockfish given differing growth, natural mortality, and selectivities between the sexes. It can accommodate the different selectivities of bottom and midwater trawling.

The SSMOD offers the theoretical advantages of a "model adapted to the conditions of the database, rather than the data .... manipulated into the structure of the database" (Methot 1989c). It explicitly allows for measurement error in any of the input parameters. Readers are referred to the publications above for details on the model's structure.

Data

Age composition data are included in both a readable (Table 10.6a and b) and SSMOD input format (Appendix Tables 10.1-3). An index of effort was calculated from 1967-1987 observations (therefore differing from Table 10.1). The time series was standardized for horsepower class and normalized to have a mean of 1.0 t/hr. The value for 1967 was too high to be reasonable, (>10t/hr) probably because of low landings (19 t), so we used the mean of the time series for the first year (Table 10.7).

Von Bertalanffy growth parameters are from Archibald et al (1981). We used a common length/weight relationship for both sexes (Jack Tagart, pers. comm.):

$$WT_{(kg)} = 0.0000185 \times L_{(cm)}^{\ 2.959}\ .$$

While age composition data were input with age-classes 5-30+, runs were conducted using a final truncated age of 25+. Ageing data were available for 1975-77, 1979-83, and 1985-86. Length data were used for 1969-74, 1978, and 1984. We used ten length classes (<36, 36-40, 41-42,43-44, 45-46, 47-48, 49-50, 51-52, 53-54, and 55+ cm).

Model Performance

The overall log likelihood function is the weighted sum of the log likelihoods for age composition, length composition and effort observations, where the relative weighting can be termed "emphasis factors" (Methot 1989c). If all the component likelihood functions were correctly defined, the emphasis factors would be 1.0. Since we assume that length observations are less reliable than age composition data, we used emphasis values of 0.3 and 0.5 for the two factors respectively. We used 0.5 for the effort data. The results were not sensitive to minor changes in these values.

Selectivities were fit to a double logistic function which allowed selectivities to reflect a dome-shaped curve with age (Figures 10.4 and 10.5). Selectivities of young fish (<12 years) were lower in the midwater fishery. This produces the higher mean sizes for midwater trawl samples. The model fit a linear function of ageing imprecision versus age. It indicated a 3% error at age 5 rising to 15% by age 25+.

Initial runs fixed M at 0.06 and 0.10 for males and females respectively (Archibald et al. 1981). These values caused the model to estimate very large values of starting biomass (>150,000 t). When allowed to fit M, the model selected values of approximately 0.09 and 0.12-0.14. At these levels of M, the model produced more realistic starting biomass values of less than 100,000 t. The final run was conducted using model selected values of 0.087 and 0.127.

The model estimates of year-class sizes agree in timing with sampling observations. Relative peaks were observed for 1961-1962, 1968-1970 and 1974-1977 (Figure 10.6). The relative sizes of the more recent peaks estimated by the model are not reliable. These cohorts (>1977) have only just started recruiting to the fishery. Because of the low selectivities at these ages, the model expects them to represent very low proportions in the catch. If samples contain even a few more young fish than expected, recruitment estimates will be grossly inflated for recent years.

The fit of expected to observed age or size composition is difficult to summarize because of the volume of data. The fit between observed and expected mean age is reasonable for males but is biased towards predicting a greater mean age of females in earlier years (1975-1983) and a younger mean age in 1984 and 1986 (Figures 10.7 and 10.8). The source of this bias is unknown.

The Q.C.Sd. analysis indicated a starting available biomass of 67,000 t. This declined to a minimum of 42,600 t in 1983, then began rising (Table 10.8, Figure 10.9). While harvests may have contributed to the decline, estimates of F were much lower than M. The stock appears to have made a resurgence following moderate to large recruitment starting with the 1974 year-class. The fishery seems to have had a relatively minor impact and stock trends have been largely recruitment driven. The recent large year-classes have been produced by the smallest spawning biomasses of the time series.

The second stock scenario included all landings and samples from Q.C.Sd. as well as those from northern B.C. and the Nootka fishery. We used the same parameter values as in the Q.C.Sd. model except that the midwater trawl fishery was treated separately in the model. Effort data were not included given the short time series of Nootka observations.

The model performed more poorly with this data set. The objective function value was much lower (-2000 vs -700 to -400) and the results were less stable in that they were more sensitive to relatively small changes in parameter values or emphasis factors. As such, we have not included a detailed presentation of results. Qualitatively, the model tended to indicate a much smaller starting biomass (35,000 t). It appeared to interpret the low catches from 1980-84 as being caused in part by the Polish fishery of 1975 and 1976. The model then accounted for the impact of this 10,000 t removal by assuming a smaller starting biomass. The Q.C.Sd. model, without the large catches in the 1970s, attributed the decline to poor recruitment. When we removed the Polish landings from the coastwide scenario, it produced biomass estimates similar to the Q.C.Sd. results.

Results

While the Q.C.Sd. model performs reasonably in some respects, there are some incongruities in the output. These include the bias in estimating mean size of females, the excessive recruitment indices in recent years, and the unexplained decline in selectivity value at age for bottom trawl caught females and midwater caught males and females.

There are also some generic problems of catch-at-age analysis that apply to this treatment. Catch-at-age analyses are most accurate when they can be tuned with some confidence to independent information on absolute or relative abundance. While we have tuned this analysis with bottom trawl catch rates, we consider catch per hour of trawl time an unreliable index of abundance for a schooling midwater species.

Catch-at-age analyses are most reliable for their characterization of earlier years in the time series. Note in Figure 10.9, that if one ignores the most recent years, the analysis indicates a declining biomass.

Finally, the model's estimate of 67,000 t for a starting biomass seems very large in comparison with the estimated virgin biomass of 90,000 t for Goose Island Gully Pacific ocean perch (Leaman and Stanley 1985). We know of no evidence, anecdotal or otherwise, to suggest that the two biomasses were comparable.

Managers must keep in mind the limited amount of information that the model is being provided and therefore the preliminary nature of the analysis. We accept the model's qualitative indication that current stock levels are similar to starting biomass levels and that therefore there is no indication of overfishing. We have little confidence in the model's prediction of absolute biomass.

10.1.2.6. Yield Forecasts

Queen Charlotte Sound

Sustainable yield estimates are typically derived from forward simulations. Analytically derived estimates of current biomass are combined with recruitment projections to test different exploitation scenarios. The present analysis and information base does not lend itself to this approach. Terminal estimates of biomass are highly variable and sensitive to almost all the parameters. Individual year-class estimates are best for only the earliest years and even then are poorly determined. Pope (1972) suggested that estimates of cohort strength only become reliable once a cohort has been exposed to cumulative F of 2.0. According to the model results (Table 10.8), the maximum cumulative F for cohorts fully recruited in 1967 would only equal 0.53 by 1987. In subsequent years, as we append more catch-at-age information, we will attempt forward projections. In the interim our assessments are based on the initial and midterm estimates of available biomass.

Alverson and Pereyra (1969) suggest that MSY can be achieved with a harvest rate equal to the natural mortality rate when the biomass is 50% of its virgin level:

$$B_{msy} = 0.5 * B_0,$$

$$MSY = M * B_{msy},$$

where B_{msy} is the biomass at the point of MSY. B_0 is biomass at time zero (67,273t). An M of 0.107, the mean of the model selected values for males and females (0.087 and 0.127), provides an MSY of 3600 t.

If the stock is not currently at the point of MSY (33600 t), then harvest can be increased or constrained accordingly. Since the recent estimates in catch-at-age analyses are the least reliable, we suggest that the estimate of current available biomass be equal to the mean of the estimates for 1980-84 period, or 43500 t. This indicates a current surplus of 9900 t (43500 t - 33600 t). We strongly suggest that managers consider this surplus, and this assessment as a whole, with caution.

The historical average of 1400 t for Q.C.Sd. is our minimum estimate of sustainable yield. There is little evidence to suggest that historical harvests have caused overfishing. The model-based estimate of 3600 t is an estimate of a sustainable yield which theoretically represents a level associated with an equal probability of overfishing as underfishing. However, harvests have only exceeded 3000 t twice in the past and those were taken from a virgin biomass in 1972 and 1973. We therefore have no direct information on the impact of sustained harvests of this magnitude.

10.1.2.7. Yield Recommendations

Queen Charlotte Sound

While, the SSMOD analysis indicates an MSY of 3600 t, owing to the preliminary nature of the analysis, we suggest a harvest range for Q.C.Sd. of 1400-3600 t. Managers may choose higher yields to "test" the productivity of the stock, prepare more "contrast" in the observations to improve the analyses, or to take advantage of the apparent 9900 t of surplus. However, we would suggest that until more years of age composition have been collected in conjunction with some independent assessments of biomass, harvests in excess of 3600 t should be considered high risk.

North Coast

This fishery has never been large. We suggest that managers consider a ceiling quota of 500 t. If a coastwide quota is more practical, then an amount approximately equal to the mean landings for this fishery, 160 t (1976-1987) should be added to the chosen Q.C.Sd. quota.

Central and Northern Vancouver Island

We have no information with which to determine the stock relationship of the Nootka fish with other populations. The fishery has been too short to analyze independently and an attempt to examine data from this fishery with the Q.C.Sd. information was not successful. In both the Polish fishery and the recent domestic midwater fishery, catch rates declined 50% after the first year (1975-1976).

We suggest that, until the stock relationships of this population are more clearly understood and there are time series of age and size composition, controls be put on this harvest. Given that our best estimate of MSY for Q.C.Sd. is 3600 t, a sustainable harvest for a fishing ground concentrated on a small area west of Nootka Inlet should be much smaller. We recommend a yield range of 500-1000 t. If coastwide quotas are more practicable, we suggest adding the value chosen from the above range to the coastal Q.C.Sd. yield.

Southern Vancouver Island

It is apparent from the tagging study that this population is continuous with fish in U.S. waters. U.S. biologists are currently revising their assessments using SSMOD. They are examining two scenarios. Both exclude the Nootka fishery. One uses data only from U.S. waters. The second scenario includes landings and samples from the Canadian portion of 3C (southwest Vancouver Island). The traditional Canadian domestic fishery in this Area has been very small (Table 10.9) and only recently has reached 300 t annually, mostly in conjunction with the domestic hake fishery. The offshore hake fishery averages an additional catch of 300 t (Table 10.2).

We recommend that this population be managed separately from fisheries to the north. We recommend joint management with the U.S. If this is unacceptable, the managers might consider a minor directed fishery (i.e., 300 t) in addition to the offshore hake fishery bycatch.

Summary

Area	Recommendation		
3C	Joint management with U.S. and a ceiling quota for domestic trawling.	-	300 t
3D	Low risk sustainable	-	500 t
	High risk sustainable	-	1000 t
5A+5B	Low risk sustainable	-	1400 t
	High risk sustainable	-	3600 t
5C+5D+5E	Ceiling yield option	-	(500) t

10.2. Strait of Georgia (Area 4B)

Catches of shelf rockfish are insignificant in the Strait of Georgia.

10.3. West Coast Vancouver Island (Areas 3C+3D)

10.3.1. Silvergray rockfish

10.3.1.1. Landing Statistics

Silvergray rockfish landings equalled 1197 t in 1988 (Table 10.10 and Figure 10.10). The 21-year mean (1967-1987) is 530 t. Large harvests from 1977-1979 were mostly from Area 3C-U.S. Catch rates indicate a stable or slightly increasing trend since 1984.

10.3.1.2. General Biological Information

No new biological information has been collected since the last assessment. As reviewed previously, samples collected during the 1985-1986 charters indicated a Z for males of 0.136 and 0.155 for females. These are high relative to our best estimates of M of 0.03-0.07 (Archibald et al. 1981).

10.3.1.3. Yield Options

Catch rates appear stable but as suggested in the previous assessment, the chronically low catch rate, the complete absence of major fisheries prior to controlled harvests, and a high Z to M ratio, supports the assumption that the stock cannot sustain harvests significantly in excess of the 21-year mean of 530 t. We continue to recommend a yield range of 400-600 t for Area 3C+3D.

10.3.2. Canary rockfish

10.3.2.1. Landing Statistics

Landings were 313 t in 1988 (Table 10.11 and Figure 10.11), well below the 21-yr average (1967-1987) of 700 t. Annual catch rates continue to decline since the advent of a significant Canadian domestic fishery on this stock (1982-1988).

10.3.2.2. General Biological Information

Length frequency observations collected during the 1988 charter and from 1989 commercial landings were examined with the graphical approach documented in the previous assessments (Stanley 1988). Under the assumption of an M of 0.05 (Archibald et al. 1981), the male size composition is consistent with an F of 0.10 (Figure 10.12). Female size composition reflects an F of 0.20 (Figure 10.13) in comparison with our estimate of 0.11 for M. Since the implied F's are twice as large as our best estimates of M for both sexes, the length composition indicates a rate of fishing which will ultimately lead to overfishing.

10.3.2.3. Yield Options

The continued decline in catch rates can no longer be perceived as sampling variation. It suggests that biomass has declined because of recruitment failures, overfishing or both, over the last 10-20 years. In either event, harvests approaching the longterm average of 700 tons are considered excessive. We recommend a yield range of 400-600 t, 100 t lower than proposed last year.

10.4. Queen Charlotte Sound (Area 5A+5B)

10.4.1. Silvergray Rockfish

10.4.1.1. Landing Statistics

The landings of 1051 t of silvergray rockfish in 1988 were the second highest ever for the Canadian domestic fishery and third highest overall (Table 10.12 and Figure 10.14). Including landings of 738 t by Japanese trawlers in the 1970s, the mean annual harvest between 1967-1987 was 700 t. Catch rates appear stable since the advent of the Canadian domestic fishery in 1978.

10.4.1.2. General Biological Information

Length frequency observations from 1988 samples were compared with theoretical distributions (Figures 10.15 and 10.16). The right limb of the distributions for both males and females corresponded to an F of 0.10 assuming M=0.04. Earlier samples (1982,1983,1986) had bimodal distributions and are not comparable.

10.4.1.3. Yield Options

Like some of the other shelf rockfish stocks, the chronically low nominal catch rates and lack of major landings throughout the history of this fishery, even in the absence of catch restrictions, implies a relatively small biomass. The size composition from 1988 samples indicates that exploitation has had an impact on the stock. That the estimate of F is considerably higher than our best estimates of M, indicates that the impact is greater than what can be sustained over the long term. A consistent catch rate in recent years, however, implies a stable biomass.

The stable catch rates indicate that the average of annual landings over the last 20 years can be considered a minimum estimate of sustainable yield, but the size composition implies that exploitation cannot be increased above that level. Managers may wish to maintain a harvest in excess of the longterm average but we doubt that significantly increased harvests are sustainable. We recommend a harvest range of 700-850 t, down from the previous range of 700-1000 t.

10.4.2. Canary Rockfish

10.4.2.1 Landing Statistics

Landings equalled 544 t in 1988 (Table 10.13). Annual landings have averaged 370 t between 1967 and 1987. Catch rates are highly variable with no clear trend although the preliminary estimate for 1989 indicates an increase (Figure 10.17).

10.4.2.2. General Biological Information

We collected two samples in 1988. The length frequency of the males corresponds to an F of 0.05, assuming M=0.05 (Figure 10.18). A similar analysis for females indicates an F of close to 0.0, what could be predicted for an unfished population (Figure 10.19). While this probably indicates that the estimate of "L-infinity" used in the model is too high, it still shows that there is a substantial body of older females in the population.

10.4.2.3. Yield Options

Size compositions imply that historical yields have had little impact on the stock. Recent catch rates are encouraging. But like the other established shelf rockfish fisheries, the chronically low nominal catch rates (0.25-0.50 t/hr) from grounds that have been extensively fished for a variety of species for over 30 years suggests that there is a relatively small biomass, probably not capable of supporting significantly more yield than the historical average of 370 t.

This historical average continues to be our minimum estimate of sustainable yield. In light of the large/old fish in the 1988 samples, and the stable or increasing catch rate, managers may wish to choose a yield option a modest amount higher but we would draw their attention to the concerns over the stocks off Vancouver Island. We continue to recommend a yield range of 350-500 t.

10.5. Hecate Strait (Area 5C+5D)

10.5.1. Silvergray Rockfish

10.5.1.1. Landing Statistics

Landings from this stock, which is presumed to reside in Moresby Gully, became significant in 1977 with the advent of a Pacific ocean perch fishery in the southern part of the gully (Table 10.14). Seventy-five per cent of the landings come from a bottom trawl depth range of 120-280 m. Mean landings for 1977-1987 equalled 540 t. Landings in 1988 equalled 893 t.

The overall catch rate since 1979 has no trend but catch rates have declined significantly since 1985, when landings reached 1000 t/yr (Figure 10.20). The nominal catch rate has almost been reduced to levels seen in the longer established canary and silvergray rockfish fisheries to the south.

10.5.1.2. General Biological Information

Age composition observations indicated a rapid shift from older fish at the start of fishery in the late 70s to fish younger than 20 years of age by 1985 and 1986 (Figures 10.21 and 10.22). However, this shift occurred prior to significant harvests and must have been recruitment driven. Dominant age modes in 1988 samples show an appropriate shift of two to three years from the 1985-1986 samples, but do not provide any additional information about the status of the stock. The dramatic recruitment effect seen between 1978 and 1985 precludes using current size or age composition information to estimate mortality rates.

10.5.1.3. Yield Options

The sustainable yield option was raised from 300 to 600 t in 1983, prior to any effective quota restrictions, under the suspicion that a significant biomass might be present. We suggested that the option be maintained at that level for 3-5 years while monitoring for signs of fishery impact.

The declining catch rates in recent years would imply that a significant impact has occurred. We suspect that the recent harvests well in excess of 600 tons are unlikely to be sustainable. We no longer assume therefore that the average yield of 540 t is the minimum estimate of sustainable yield and suggest that the yield range be lowered from 500-800 to 400-600 t. Managers may wish to permit yields in excess of this level to further test the productivity of this stock but should be prepared for erosion of the resource base.

10.5.2. Canary Rockfish

The canary rockfish fishery in Hecate Strait continues to be insignificant with 134 t landed in 1988. We recommend a ceiling yield option of 500 t as in the past.

10.6. West Coast of Queen Charlotte Islands (Area 5E)

10.6.1. Silvergray Rockfish

10.6.1.1. Landing Statistics

The silvergray rockfish fisheries off the west coast of the Queen Charlotte Islands continue to be minor and incidental to the fisheries for Pacific ocean perch (Table 10.15). Less than 40% of the reported 1988 catches met a 25% qualification criteria.

No restrictions have been placed on catches of shelf rockfish north of 54° since the beginning of the experimental fishery. Over this period, landings and catch rates (0% qualification) have declined. The slight increase showing in preliminary 1989 landings may have been caused by contamination with landings from elsewhere.

10.6.1.2. Yield Options

This fishery is largely incidental to slope rockfish fishing so trip limits will not reduce catches, only increase the amount of discarding. We recommend use of a ceiling quota of 500 t for 5E-S, and no restrictions for 5E-N if the experimental fishery remains in effect.

10.6.2. Canary Rockfish

Only 84 t of canary rockfish were reported to have come from this area in 1988. Managers may wish to continue with 500 t ceiling quotas as in past years.

Table 10.1. Mean harvest (1967-1987), 1988 landings, status indicators, and suggested yield ranges for shelf rockfish.

				Status indicators			
Area	Species	Mean harvest (t)	1988 landings (t)	Small size/ low ages	Declining size/age	Catch rate	Suggested yield range (t)
3C	yellowtail	400	612[a]	unknown	unknown	unknown	0-400
3D	yellowtail	n.a.	2037	no	n.a.	declining or stable	500-1000
5A+5B	yellowtail	1400	2295	"SSMOD"	"SSMOD"	stable or increasing	1400-3600
3C+3D	silvergray	530	1197	yes	yes	stable/incr.	400-600
3C+3D	canary	700	313	yes	unknown	declining	400-600
5A+5B	silvergray	700	1051	yes	unknown	stable	700-850
5A+5B	canary	370	544	no	unknown	stable	350-500
5C+5D	silvergray	540	893	no	no	declining	400-600
	yellowtail	minor	92	(---------	unknown	---------)	ceiling range
	canary	minor	134	(---------	unknown	---------)	ceiling range
5E-N	silvergray	minor	131	unknown	unknown	stable	[b]
5E-S	silvergray	minor	255	unknown	unknown	unknown	[b]
	yellowtail	minor	16	unknown	unknown	unknown	ceiling range
5E	canary	minor	84	unknown	unknown	unknown	ceiling range

[a] Includes catch in offshore hake fishery.
[b] Recommended no trip limits.

Table 10.2. Yellowtail rockfish landings (t) from B.C. waters, 1967-1989. ("bt" = bottom trawl and "mw" = midwater trawl.)

	West coast Vancouver Island[a]					Q.C. Sound[b]			Hecate Strait, Dixon Entrance, W. coast Q.C. Island		
Year	Can. (bt)	Can. (mw)	U.S. (bt)	Poland (mw)	Offshore hake (mw)	Can. (bt)	Can. (mw)	U.S. (bt)	Can. (bt)	Can. (mw)	Total
1967	4	0	103			19	0	996	1	0	1,123
1968	0	0	23			23	0	278	0	0	324
1969	45	0	243			86	0	2,174	15	0	2,563
1970	29	0	154			160	14	2,629	17	0	3,003
1971	18	0	128			225	0	1,955	51	0	2,377
1972	14	0	76			692	3	2,735	29	0	3,549
1973	26	0	23			516	5	2,735	1	0	3,324
1974	20	0	117			150	14	809	47	1	1,158
1975	13	0	89	6,700		317	97	303	57	0	7,576
1976	86	0	72	2,339		590	38	363	164	31	3,683
1977	77	177	300			762	251	1,242	301	2	3,112
1978	83	13	169		120	1,445	201	397	273	111	2,812
1979	67	66	132		187	1,312	23	192	469	122	2,570
1980	60	8	45		142	471	0	81	124	42	973
1981	44	0	10		120	281	0		86	12	553
1982	134	1			320	280	13		87	12	847
1983	44	9			347	308	15		58	14	795
1984	42	0			350	177	18		86	30	703
1985	353	38			264	341	0		80	129	1,205
1986	1,178	2,354			311	822	0		92	12	4,769
1987	1,039	1,451			330	1,441	101		150	1	4,513
1988	[illegible],190	1,123			334	1,309	986		126	22	5,091
1989[c]	437	843			(358)	1,288	678		266	0	3,512

[a] Includes landings from Strait of Juan de Fuca.

[b] Excludes landings from Moresby Gully.

[c] To June 30, 1989.

Table 10.3 CPUE indices (t/hr) and total effort (h) for the principal domestic fisheries of yellowtail rockfish in B.C. waters[a].

	W.C. Vancouver Island						Q.C. Sound		
	Bottom trawl			Midwater trawl			Bottom trawl		
	Effort[b]	Nominal CPUE[b]	Standardized CPUE[c]	Effort[b]	Nominal CPUE[b]	Standardized CPUE[d]	Effort[b]	Nominal CPUE[b]	Standardized CPUE[c]
1972	-	-	-	-	-	-	1102	0.53	0.57
1973	-	-	-	-	-	-	936	0.53	0.47
1974	-	-	-	-	-	-	270	0.35	0.33
1975	-	-	-	-	-	-	829	0.32	0.43
1976	-	-	-	-	-	-	1347	0.29	0.45
1977	-	-	-	-	-	-	2449	0.25	0.31
1978	-	-	-	-	-	-	2493	0.51	0.48
1979	-	-	-	-	-	-	1759	0.68	0.46
1980	-	-	-	-	-	-	993	0.38	0.36
1981	-	-	-	-	-	-	570	0.33	0.37
1982	-	-	-	-	-	-	639	0.28	0.33
1983	-	-	-	-	-	-	428	0.44	0.38
1984	-	-	-	-	-	-	441	0.24	0.34
1985	322	0.80	0.54	-	-	-	557	0.45	0.40
1986	1013	0.63	0.59	1036	2.01	2.51	1341	0.46	0.56
1987	765	0.73	0.66	1201	1.06	1.19	1958	0.38	0.41
1988	930	0.79	0.60	945	1.18	1.20	2409	0.37	0.50
1989[e]	230	0.62	0.62	738	1.09	1.09	1575	0.60	0.60

[a] Time series of catch rate indices initiated once landings became significant (>250 t).
[b] 25% qualification for interviewed landings.
[c] Standardized for horsepower class and a non-linear relationship of catch and effort.
[d] Standardized for horsepower class.
[e] To June 30, 1989.

Table 10.4. Yellowtail rockfish tag releases and recoveries by International Area and year.

Year		Area					Recoveries (total)	Landings[a] (t)	Rec/ldge. (x 100)
		2B+2C	3A	3C+3B	5A+5B	4A			
1980	Released			6145	2485		4[b]		
	Recovered			3				2909	0.14
1981	Released				2137				
	Recovered			3			3	3501	0.86
1982	Released			3272					
	Recovered		3	4	1		8	4218	0.19
1983	Recovered		1		2		3	3759	0.08
1984	Recovered	1	1	2		1	5	1339	0.37
1985	Recovered			4			4	1777	0.23
1986	Recovered						0	5987	0.00
1987	Recovered		1	1	1		3	3316	0.09
1988	Recovered						0	–	0.00
Total		1	6	17	4	1	29		

[a] Areas 3B+3C+3D+5A+5B.

[b] One from unknown locale within Area 3.

Table 10.5. Comparison of pooled age composition weighted by weight or numbers in the composite samples for male yellowtail rockfish from 1986 commercial samples.

Age	Proportion (Weighted by weight)	Proportion (Weighted by number)
6	0.028	0.026
7	0.038	0.035
8	0.121	0.108
9	0.136	0.131
10	0.104	0.099
11	0.109	0.110
12	0.089	0.092
13	0.058	0.058
14	0.029	0.030
15	0.020	0.022
16	0.030	0.032
17	0.032	0.035
18	0.019	0.021
19	0.011	0.012
20	0.012	0.013
21	0.012	0.013
22	0.009	0.010
23	0.010	0.011
24	0.021	0.022
25+	0.112	0.117

Table 10.6a. Proportions of male yellowtail rockfish at age from Q.C. Sound samples (all samples for each year standardized to 1000 kg).

	Year										
Age	75	76	77	78	79	80	81	82	83	84	85	86
5	.000	.000	.000	-	.000	.000	.000	.000	.007	-	.000	.000
6	.000	.003	.000	-	.000	.000	.027	.006	.000	-	.019	.015
7	.000	.004	.021	-	.005	.000	.081	.000	.000	-	.111	.039
8	.000	.007	.048	-	.008	.004	.072	.006	.014	-	.081	.161
9	.021	.011	.027	-	.018	.016	.016	.014	.045	-	.106	.167
10	.021	.037	.035	-	.038	.075	.064	.024	.017	-	.056	.121
11	.083	.054	.007	-	.085	.071	.116	.024	.007	-	.068	.088
12	.083	.068	.034	-	.043	.060	.119	.061	.048	-	.012	.051
13	.186	.086	.020	-	.059	.064	.068	.073	.075	-	.037	.038
14	.146	.141	.047	-	.064	.030	.064	.091	.088	-	.050	.018
15	.021	.096	.053	-	.054	.034	.016	.037	.030	-	.037	.009
16	.021	.061	.068	-	.054	.030	.077	.018	.053	-	.037	.018
17	.021	.025	.061	-	.059	.041	.034	.018	.017	-	.025	.012
18	.021	.046	.021	-	.044	.045	.000	.037	.047	-	.012	.009
19	.021	.043	.021	-	.049	.041	.016	.031	.024	-	.019	.012
20	.021	.029	.035	-	.034	.072	.031	.067	.041	-	.050	.009
21	.021	.025	.028	-	.032	.019	.031	.055	.036	-	.025	.012
22	.000	.025	.021	-	.015	.015	.017	.031	.067	-	.050	.006
23	.000	.036	.034	-	.027	.030	.000	.018	.046	-	.068	.006
24	.021	.018	.028	-	.015	.019	.000	.024	.030	-	.037	.015
25	.042	.036	.027	-	.022	.011	.007	.031	.024	-	.000	.023
26	.000	.018	.014	-	.015	.015	.000	.031	.017	-	.000	.017
27	.083	.021	.034	-	.017	.026	.016	.006	.029	-	.000	.009
28	.000	.025	.054	-	.015	.011	.009	.018	.003	-	.006	.009
29	.021	.021	.028	-	.025	.015	.000	.018	.013	-	.019	.009
30+	.146	.064	.234	-	.203	.246	.119	.251	.222	-	.075	.127

Table 10.6b. Proportions of female yellowtail rockfish at age from Q.C. Sound samples (all samples for each year standardized to 1000 kg).

	Year											
Age	75	76	77	78	79	80	81	82	83	84	85	86
5	.000	.000	.000	-	.000	.000	.000	.000	.000	-	.000	.004
6	.000	.000	.000	-	.005	.000	.050	.000	.000	-	.029	.027
7	.000	.009	.103	-	.000	.000	.131	.028	.061	-	.101	.047
8	.000	.018	.039	-	.016	.008	.105	.028	.100	-	.123	.184
9	.019	.018	.082	-	.011	.008	.029	.056	.059	-	.198	.265
10	.019	.072	.104	-	.085	.136	.107	.000	.009	-	.167	.128
11	.019	.099	.039	-	.084	.190	.130	.167	.139	-	.072	.136
12	.038	.118	.060	-	.114	.236	.180	.192	.100	-	.065	.084
13	.271	.088	.099	-	.089	.122	.073	.056	.148	-	.058	.042
14	.250	.216	.178	-	.094	.015	.056	.083	.160	-	.065	.011
15	.192	.221	.098	-	.082	.038	.012	.111	.117	-	.029	.004
16	.038	.063	.121	-	.077	.053	.068	.056	.019	-	.051	.019
17	.096	.018	.039	-	.057	.053	.012	.028	.000	-	.007	.007
18	.058	.025	.019	-	.077	.038	.000	.083	.030	-	.007	.011
19	.000	.000	.019	-	.040	.015	.012	.000	.000	-	.007	.004
20	.000	.008	.000	-	.041	.022	.009	.000	.000	-	.007	.004
21	.000	.000	.000	-	.020	.015	.010	.056	.040	-	.007	.004
22	.000	.018	.000	-	.011	.007	.000	.028	.009	-	.007	.004
23	.000	.000	.000	-	.020	.000	.000	.000	.000	-	.000	.000
24	.000	.000	.000	-	.015	.000	.000	.000	.000	-	.000	.000
25	.000	.000	.000	-	.010	.007	.000	.000	.000	-	.000	.000
26	.000	.000	.000	-	.010	.000	.000	.000	.000	-	.000	.004
27	.000	.000	.000	-	.015	.000	.009	.000	.000	-	.000	.004
28	.000	.000	.000	-	.005	.000	.000	.000	.000	-	.000	.000
29	.000	.000	.000	-	.011	.000	.000	.000	.000	-	.000	.000
30+	.000	.009	.000	-	.011	.037	.007	.028	.009	-	.000	.007

Table 10.7. Catch and effort data used in SSMOD analysis of the Q.C. Sd. yellowtail rockfish fishery.

Year	Landings (t)	Effort (000's of hours)
67	1015	1.015
68	301	0.301
69	2259	2.185
70	2833	0.665
71	2180	2.806
72	3430	1.953
73	3256	2.846
74	1073	2.133
75	717	.804
76	1224	1.204
77	2255	5.356
78	2043	1.737
79	1527	1.388
80	552	.856
81	281	.256
82	293	.575
83	323	.486
84	195	.375
85	341	.461
86	822	.499
87	1542	1.404

Table 10.8. SSMOD predicted values of available biomass for Q.C. Sound yellowtail rockfish.

Year	Available biomass (t)	Observed catch (t)	% Female	"F"
1967	67273	1015	0.400	0.016
1968	66402	301	0.401	0.005
1969	66300	2259	0.401	0.036
1970	64421	2803	0.403	0.047
1971	62251	2180	0.405	0.037
1972	61522	3430	0.402	0.060
1973	59408	3256	0.397	0.059
1974	55669	1073	0.397	0.020
1975	53622	717	0.397	0.014
1976	51618	1224	0.397	0.025
1977	49182	2255	0.399	0.049
1978	46609	2043	0.399	0.047
1979	44884	1527	0.398	0.036
1980	43954	552	0.394	0.013
1981	43573	281	0.393	0.007
1982	42880	293	0.399	0.007
1983	42625	323	0.414	0.008
1984	44325	195	0.435	0.005
1985	49627	341	0.465	0.007
1986	60291	822	0.493	0.014
1987	79280	1542	0.496	0.021

Table 10.9. Total domestic trawl landings of yellowtail rockfish from Canadian portion of Area 3C.

Year	Landings (t)
1967	1
1968	0
1969	22
1970	10
1971	10
1972	11
1973	20
1974	17
1975	6
1976	50
1977	57
1978	45
1979	36
1980	37
1981	17
1982	115
1983	15
1984	20
1985	94
1986	430
1987	501
1988	278

Table 10.10. Area 3C and 3D landings (t), effort (h), and nominal CPUE (t/h) of silvergray rockfish 1967-1989.

		Total	Interviewed			Interviewed (25% qual.)		
Year	Nat.	landings[a]	Landings[b]	Effort [c]	CPUE	Landings	Effort	CPUE
1967	USA	196	195	4471	.04	-	-	-
1968	USA	205	200	2928	.07	-	-	-
1969	USA	334	334	3647	.09	-	-	-
1970	Can	2	2	119	.02	1	1	1.00
	USA	371	358	4785	.07	-	-	-
1971	Can	5	5	48	.10	2	2	1.00
	USA	161	161	3009	.05	-	-	-
1972	USA	442	442	2969	.15	-	-	-
1973	USA	227	227	2619	.09	-	-	-
1974	Can	1	1	12	.08	-	-	-
	USA	236	235	2666	.09	-	-	-
1975	Can	4	4	44	.09	0	0	-
	USA	113	113	2938	.04	-	-	-
1976	Can	5	5	9	.55	0	0	-
	USA	326	326	3945	.08	-	-	-
1977	Can	28	28	516	.05	17	28	.61
	USA	1035	1035	5427	.19	-	-	-
1978	Can	22	22	284	.08	1	8	.13
	USA	972	972	6244	.16	-	-	-
1979	Can	22	22	131	.17	13		
	USA	1248	1248	4812	.26	-	-	-
1980	Can	23	23	214	.11	9	15	.60
	USA	764	764	3848	.20	-	-	-
1981	Can	15	15	77	.19	9	24	.38
	USA	284	284	5424	.05	-	-	-
1982	Can	129	129	388	.33	124	126	.99
	USA	60	60	11,819	.01	-	-	-
1983	Can	646	646	1455	.44	390	837	.47
1984	Can	570	335	1644	.20	237	658	.36
1985	Can	921	349	1242	.28	273	521	.52
1986	Can	1093	690	3135	.22	474	906	.52
1987	Can	604	516	2199	.24	323	458	.72
1988	Can	1197	1007	3878	.26	644	1217	.53
1989[d]	Can	429	375	2121	.18	274	496	.55

[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort from Washington only (Tagart and Kimura 1982).

[d] To June 30, 1989.

Table 10.11. Area 3C and 3D landings (t), effort (h), and nominal CPUE (t/h) of canary rockfish, 1967-89.

		Total	Interviewed			Interviewed (25% qual.)		
Year	Nat.	landings[a]	Landings[b]	Effort[c]	CPUE	Landings	Effort	CPUE
1967	USA	578	575	4,471	.13	-	-	-
	Can	4	4	41	.10	1	8	.12
1968	USA	938	902	2,838	.32	0	0	-
	Can	19	19	157	.12	10	12	.83
1969	USA	779	746	3,647	.20	-	-	-
	Can	46	46	266	.17	42	127	.33
1970	USA	990	938	4,785	.20	-	-	-
	Can	18	18	96	.19	17	89	.19
1971	USA	1,011	962	3,009	.32	-	-	-
	Can	66	66	533	.12	52	235	.22
1972	USA	294	292	2,969	.10	-	-	-
1973	USA	493	490	2,619	.19	-	-	-
1974	Can	26	26	461	.06	15	26	.58
	USA	607	605	2,666	.23	-	-	-
1975	Can	14	14	186	.08	9	10	.90
	USA	658	658	2,938	.22	-	-	-
1976	Can	193	193	822	.23	157	207	.76
	USA	395	395	3,945	.10	-	-	-
1977	Can	196	196	1,808	.12	109	147	.74
	USA	358	358	5,427	.07	-	-	-
1978	Can	68	68	434	.16	40	56	.71
	USA	1,063	1,063	6,244	.17	-	-	-
1979	Can	122	114	680	.17	94	175	.54
	USA	315	315	4,812	.07	-	-	-
1980	Can	126	126	1,058	.12	109	204	.53
	USA	477	477	3,848	.12	-	-	-
1981	Can	66	66	929	.07	42	84	.50
	USA	249	249	5,424	.05	-	-	-
1982	Can	316	316	1,415	.22	286	309	.93
	USA	133	133	11,819	.01	-	-	-
1983	Can	853	647	1,723	.38	593	1,049	.57
1984	Can	1,189	947	1,079	.46	916	1,170	.78
1985	Can	903	611	1,897	.32	557	779	.72
1986	Can	722	529	2,841	.19	344	651	.53
1987	Can	695	600	2,535	.24	462	670	.69
1988	Can	313	291	2,085	.14	176	516	.34
1989[d]	Can	380	328	2,397	.14	241	643	.38

[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort from Washington only (Tagart and Kimura 1982).

[d] To June 30, 1989.

Table 10.12. Area 5A and 5B landings (t), effort (h), and CPUE (t/h) of silvergray rockfish, 1967-89.

			Interviewed			Interviewed (25% qual.)		
Year	Nat.	Total landings[a]	Landings[b]	Effort[c]	CPUE	Landings	Effort	CPUE
1967	CAN	87	89	539	.17	63	200	.32
	USA	397	396	9,431	.04	–	–	–
1968	CAN	78	78	644	.12	37	109	.34
	USA	933	822	8,488	.10	–	–	–
1969	CAN	78	78	1188	.07	28	152	.18
	USA	1,291	1,276	13,557	.09	–	–	–
1970	CAN	14	14	287	.05	6	29	.21
	USA	189	189	9,264	.02	–	–	–
1971	CAN	16	16	331	.05	6	66	.09
	USA	521	512	7,137	.07	–	–	–
1972	CAN	54	54	654	.08	21	108	.19
	USA	251	251	9,224	.03	–	–	–
1973	CAN	40	40	328	.12	33	70	.47
	USA	189	189	9,625	.02	–	–	–
1974	CAN	45	45	412	.11	9	12	.75
	USA	377	377	8,797	.04	–	–	–
1975	CAN	31	31	479	.06	19	61	.31
	USA	306	306	5,179	.06	–	–	–
1976	CAN	172	172	1,914	.09	82	224	.37
	USA	443	443	4,620	.10	–	–	–
1977	CAN	198	198	2,462	.08	123	320	.38
	USA	440	440	5,165	.09	–	–	–
1978	CAN	723	723	4,049	.18	468	1,069	.44
	USA	57	57	909	.06	–	–	–
1979	CAN	629	629	3,885	.16	429	1,225	.35
	USA	298	298	1,696	.18	–	–	–
1980	CAN	629	625	3,681	.17	495	1,538	.32
	USA	147	147	1,146	.13	–	–	–
1981	CAN	415	415	2,120	.20	340	808	.42
1982	CAN	618	597	4,099	.15	430	1,208	.36
1983	CAN	524	477	3,348	.14	323	1,073	.30
1984	CAN	982	718	3,481	.21	642	1,948	.33
1985	CAN	997	724	3,555	.20	611	1,860	.33
1986	CAN	700	564	3,812	.15	388	1,314	.30
1987	CAN	1,224	1,083	6,509	.17	641	1,596	.40
1988	CAN	1,051	1,016	7,232	.14	596	1,554	.38
1989[d]	CAN	387	326	2,293	.14	217	583	.37

[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort for Washington only (Tagart and Kimura 1982).

[d] To June 30, 1989.

Table 10.13. Area 5A and 5B landings (t), effort (h), and CPUE (t/h) of canary rockfish, 1967-89.

		Total	Interviewed			Interviewed (25% qual.)		
Year	Nat.	landings[a]	Landings[b]	Effort[c]	CPUE	Landings	Effort	CPUE
1967	CAN	41	41	535	.08	13	32	.41
	USA	216	215	9,431	.02	-	-	-
1968	CAN	49	49	576	.09	31	78	.40
	USA	1,034	937	8,488	.11	-	-	-
1969	CAN	67	67	733	.09	37	110	.34
	USA	464	418	13,557	.03	-	-	-
1970	CAN	6	6	80	.08	4	12	.33
	USA	220	220	9,264	.02	-	-	-
1971	CAN	18	18	329	.05	6	8	.75
	USA	207	183	7,137	.03	-	-	-
1972	USA	61	61	9,224	.01	-	-	-
1973	CAN	29	29	119	.24	23	80	.29
	USA	298	298	9,625	.03	-	-	-
1974	CAN	3	3	81	.04	1	7	.14
	USA	257	257	8,797	.03	-	-	-
1975	CAN	23	23	403	.06	15	17	.88
	USA	189	189	5,179	.04	-	-	-
1976	CAN	92	92	1,558	.06	16	49	.33
	USA	447	447	4,620	.10	-	-	-
1977	CAN	121	121	2,356	.05	53	192	.28
	USA	288	288	5,165	.06	-	-	-
1978	CAN	263	263	2,692	.10	101	242	.42
	USA	8	8	909	.01	-	-	-
1979	CAN	308	308	3,070	.10	211	582	.36
	USA	62	62	1,696	.04	-	-	-
1980	CAN	276	276	2,157	.13	198	451	.44
	USA	88	88	1,146	.08	-	-	-
1981	CAN	144	144	1,636	.09	69	201	.35
1982	CAN	358	330	3,203	.10	210	706	.30
1983	CAN	343	299	2,851	.11	152	454	.33
1984	CAN	507	321	2,506	.13	228	686	.33
1985	CAN	391	281	2,823	.10	162	553	.29
1986	CAN	262	211	2,931	.07	64	253	.25
1987	CAN	560	510	4,248	.12	245	572	.43
1988	CAN	544	529	5,792	.09	195	652	.30
1989[d]	CAN	281	208	1,908	.11	132	278	.48

[a] U.S. total landings equals Washington and Oregon combined.

[b] U.S. interviewed landings from Washington only (Tagart and Kimura 1982).

[c] U.S. interviewed effort represents total rockfish effort for Washington only (Tagart and Kimura 1982).

[d] To June 30, 1989.

Table 10.14. Area 5C and 5D landings[a] (t), effort (h), and CPUE (t/h) of silvergray rockfish, 1971-89.

Year	Total landings	Interviewed			Interviewed (25% qual.)		
		Landings	Effort	CPUE	Landings	Effort	CPUE
1971	34	34	229	.15	24	121	.20
1972	61	61	232	.26	44	54	.81
1973	10	10	147	.07	-	-	-
1974	13	13	64	.20	11	34	.33
1975	11	11	190	.06	4	5	.79
1976	118	118	1,440	.08	55	414	.13
1977	232	232	2,019	.12	142	468	.30
1978	235	235	1,413	.17	177	301	.59
1979	429	429	3,029	.14	285	701	.41
1980	346	344	1,938	.18	186	396	.47
1981	456	415	1,762	.24	343	311	1.10
1982	259	238	1,799	.13	149	212	.70
1983	451	348	1,108	.31	289	337	.86
1984	647	383	2,081	.18	315	710	.44
1985	1,043	729	2,133	.34	578	458	1.26
1986	1,082	1,056	1,796	.59	1,024	927	1.10
1987	763	632	1,928	.33	531	592	0.90
1988	893	881	3,270	.27	625	1,064	0.59
1989[b]	520	509	4,211	.36	382	574	0.57

[a] No history of U.S. fishing on this stock.
[b] To July 10, 1989.

Table 10.15. Area 5E-N and 5E-S landings (t), effort (h), and CPUE (t/h) of silvergray rockfish, 1977-89.

		Total	Interviewed			Interviewed (25% qual.)		
Year		landings	Landings	Effort	CPUE	Landings	Effort	CPUE
1977	S	20	20	136	.15	0	0	-
	N	0	0	0	-	0	0	-
1978	S	124	124	572	.22	56	105	.53
	N	16	16	91	.18	16	21	.76
1979	S	44	44	189	.23	30	19	1.58
	N	8	8	95	.08	0	0	-
1980	S	104	104	246	.42	81	97	0.84
	N	15	15	17	.91	15	17	.91
1981	S	57	22	74	.30	12	12	1.00
	N	2	2	10	.20	0	0	-
1982	S	27	22	152	.14	7	4	1.75
	N	38	30	56	.54	27	9	3.00
1983	S	130	130	414	.31	44	58	.76
	N	16	11	108	.10	1	1	1.00
1984	S	78	71	246	.29	47	104	.45
	N	248	233	731	.32	61	33	1.88
1985	S	212	175	466	.38	85	142	.60
	N	245	245	1,258	.20	158	219	.72
1986	S	295	245	601	.41	112	154	.73
	N	172	170	1,772	.10	35	39	.89
1987	S	113	102	586	.17	30	53	.58
	N	85	83	1,004	.08	6	21	.30
1988	S	255	244	1,001	.24	108	96	1.13
	N	131	131	1,521	.09	40	76	.53
1989[a]	S	64	64	277	.23	44	66	.67
	N	196	195	853	.23	77	97	.79

[a] To June 30, 1989.

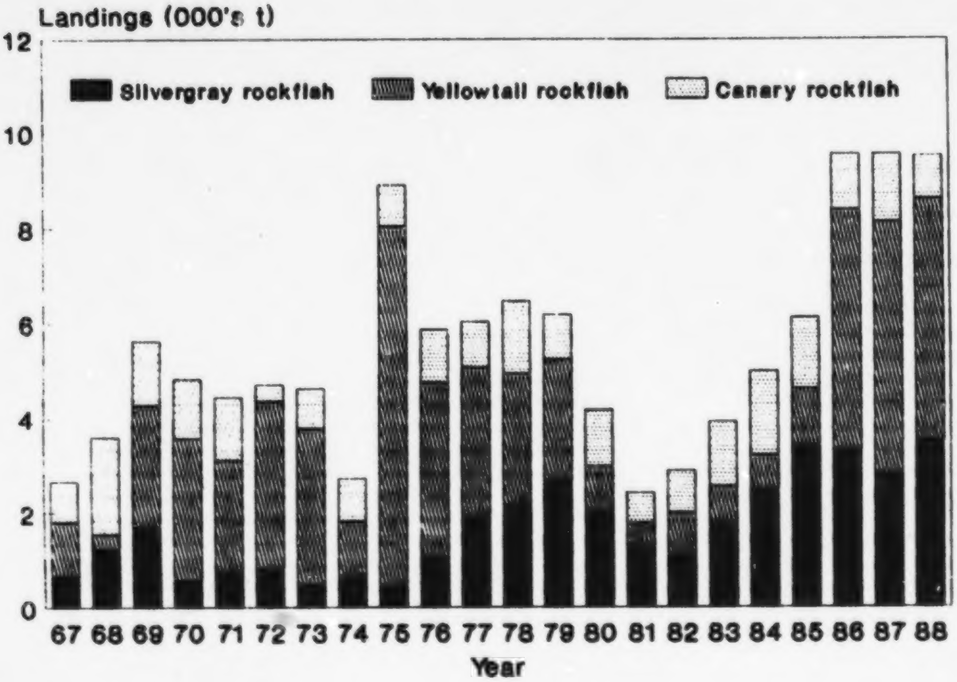


Fig. 10.1. Combined shelf rockfish landings from B.C. waters.

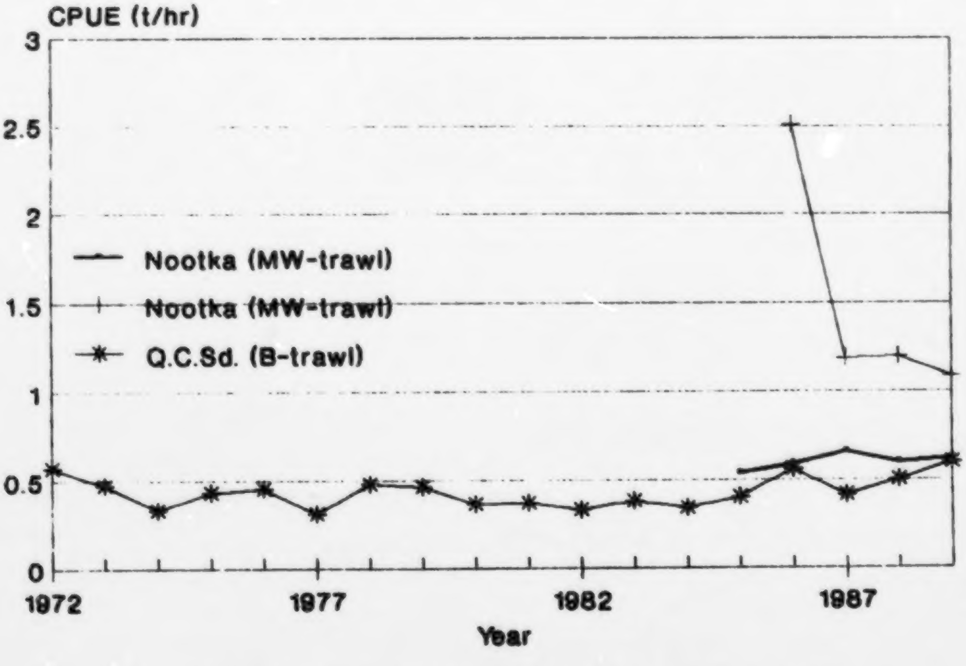


Fig. 10.2. Yellowtail rockfish CPUE in Canadian waters.

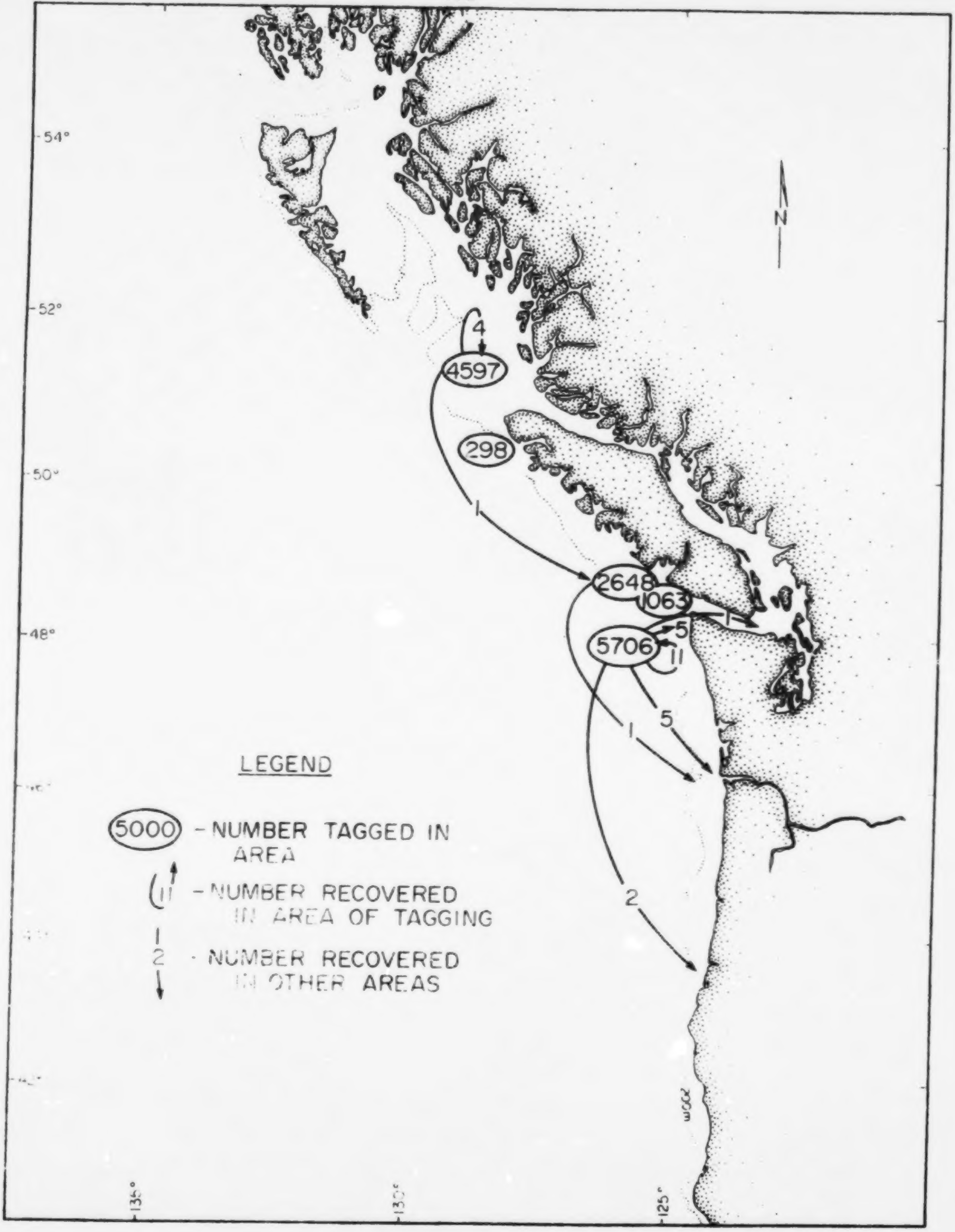

54°
52°
50°
48°
135°
130°
125°
N
500m
4
4597
298
1
2648
1063
1
5
5706
11
5
1
2
LEGEND
5000 - NUMBER TAGGED IN AREA
11 - NUMBER RECOVERED IN AREA OF TAGGING
1 2 - NUMBER RECOVERED IN OTHER AREAS

Fig. 10.3. Yellowtail rockfish tag recoveries.

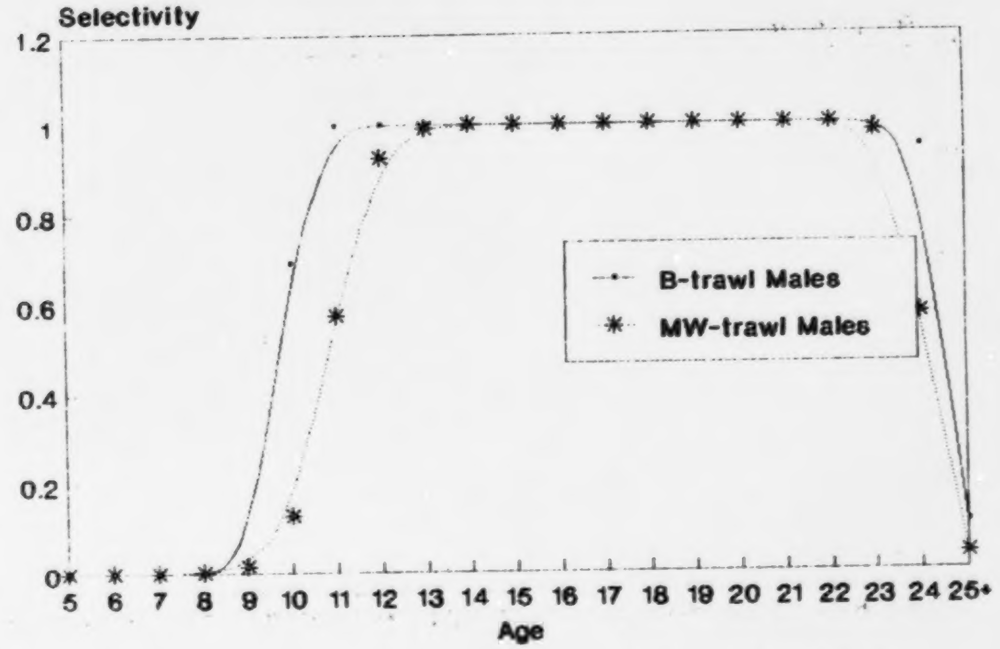


Fig. 10.4. Selectivity factors for male yellowtail rockfish.

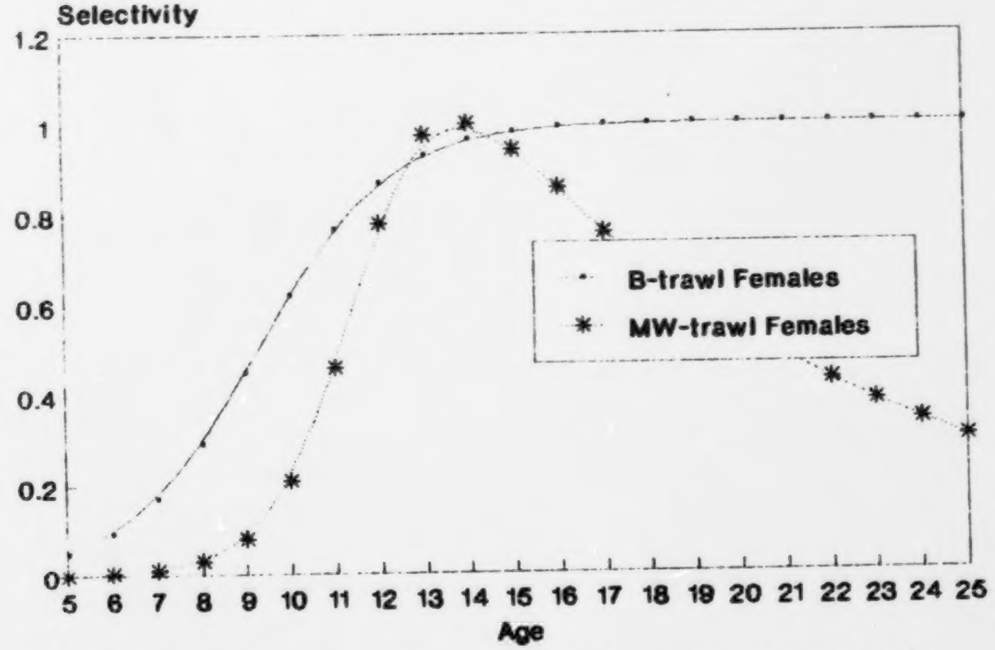


Fig. 10.5. Selectivity factors for female yellowtail rockfish.

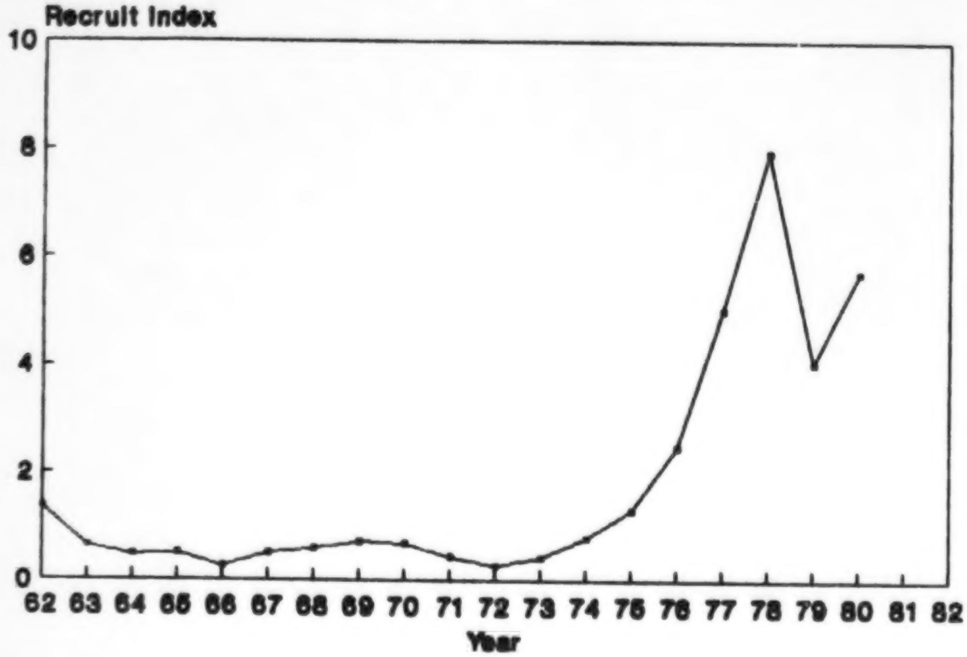


Figure 10.6. Relative recruitment indices for Queen Charlotte Sound yellowtail rockfish.

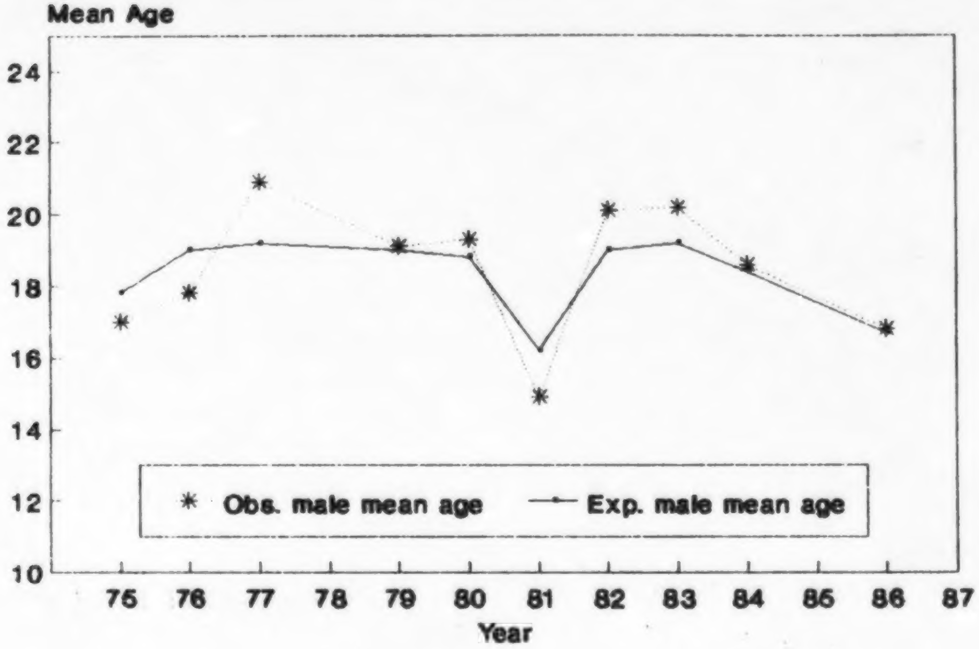


Fig. 10.7. Comparison of observed mean age and SSMOD predicted mean age for male yellowtail rockfish.

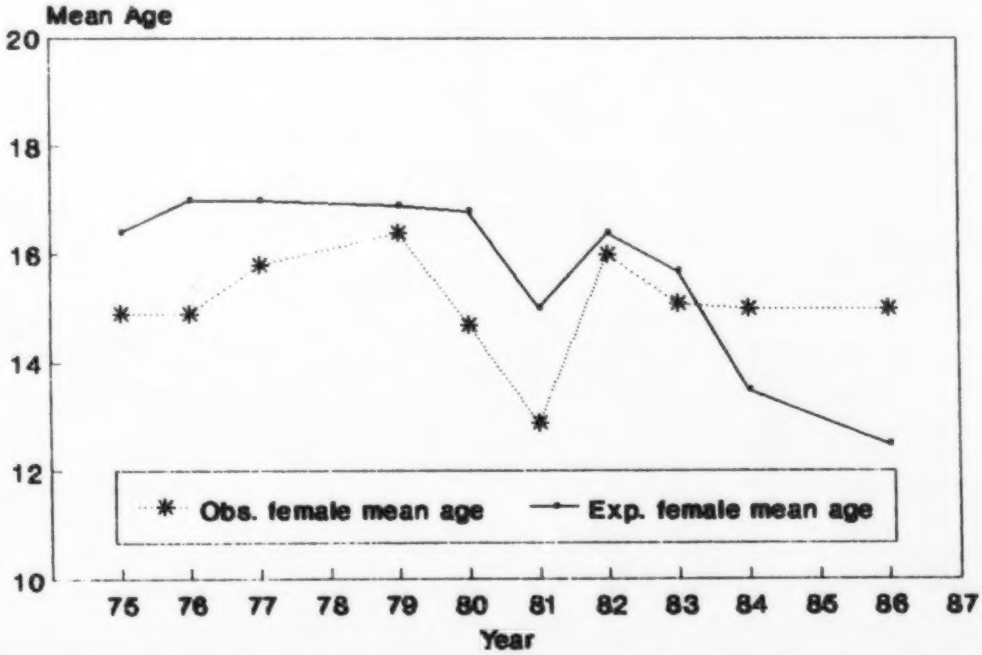


Fig. 10.8. Comparison of observed mean age and SSMOD predicted mean age for female yellowtail rockfish.

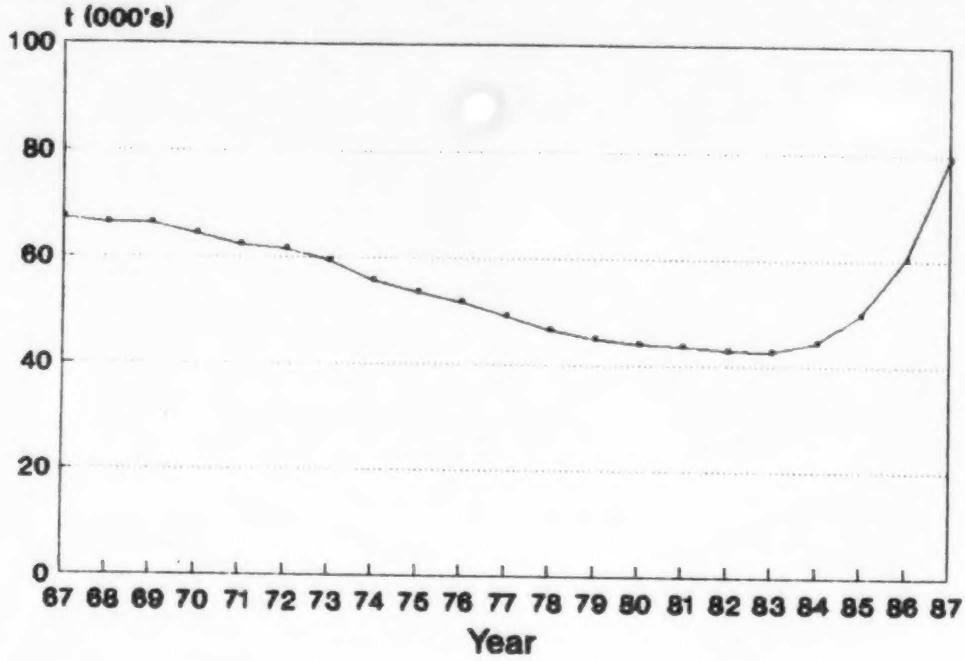


Fig. 10.9. Predicted values of available biomass for yellowtail rockfish in Queen Charlotte Sound.

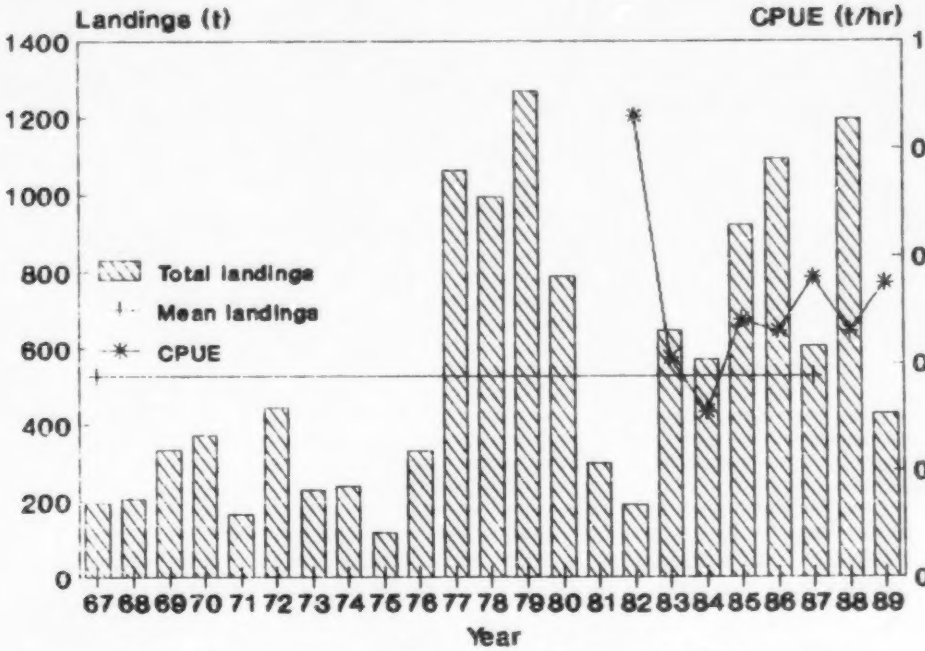


Fig. 10.10. Silvergray rockfish landings and CPUE in Areas 3C and 3D.

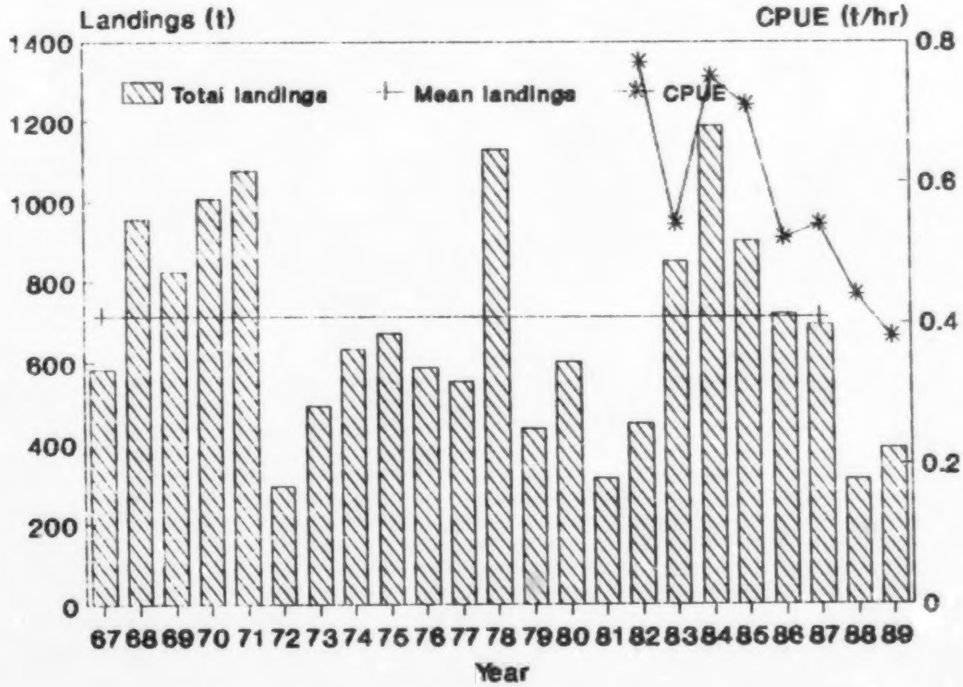


Fig. 10.11. Canary rockfish landings and CPUE in Areas 3C and 3D.

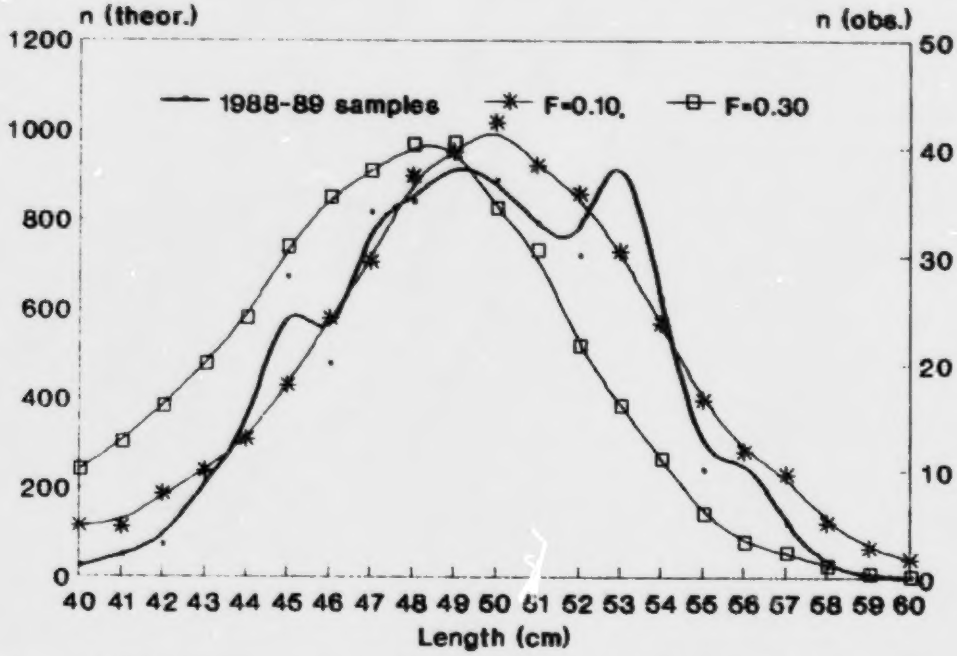


Fig. 10.12. Theoretical and observed length frequencies for male canary rockfish from Areas 3C and 3D.

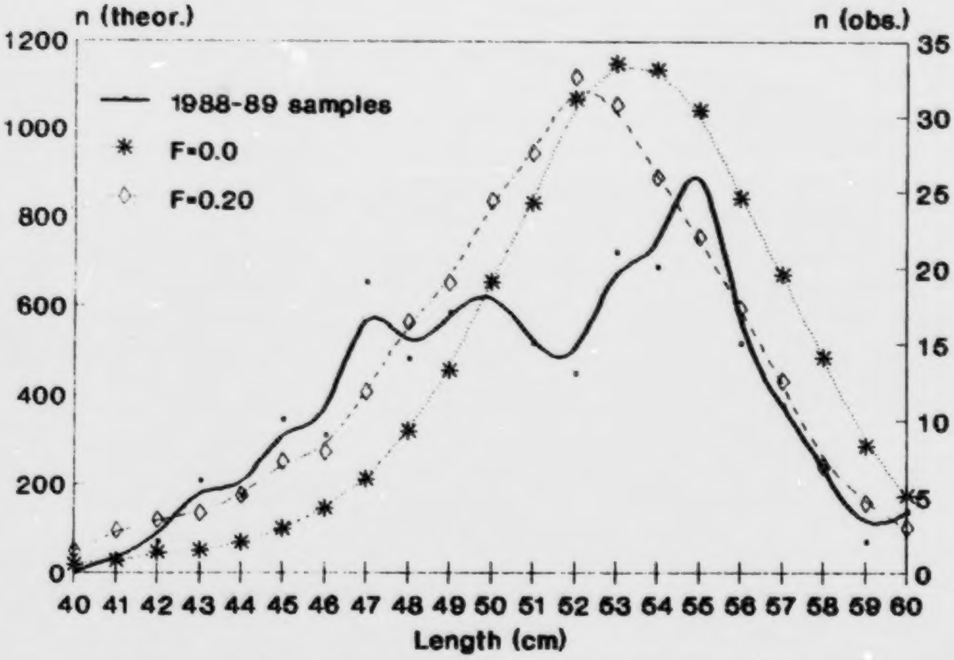


Figure 10.13. Theoretical and observed length frequencies for female canary rockfish from Areas 3C and 3D.

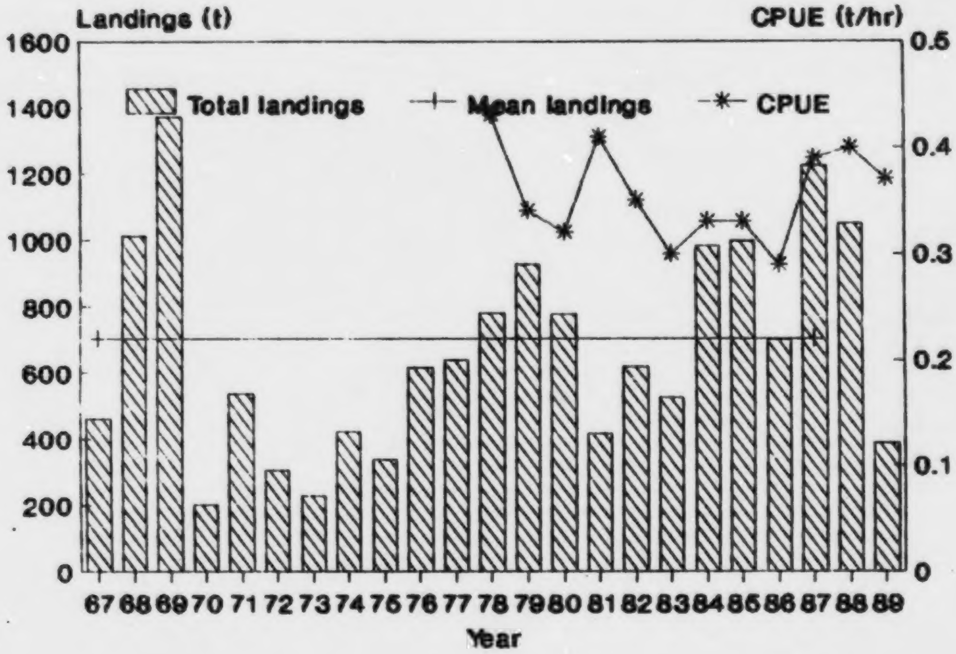


Fig. 10.14. Silvergray rockfish landings and catch rates for Areas 5A and 5B.

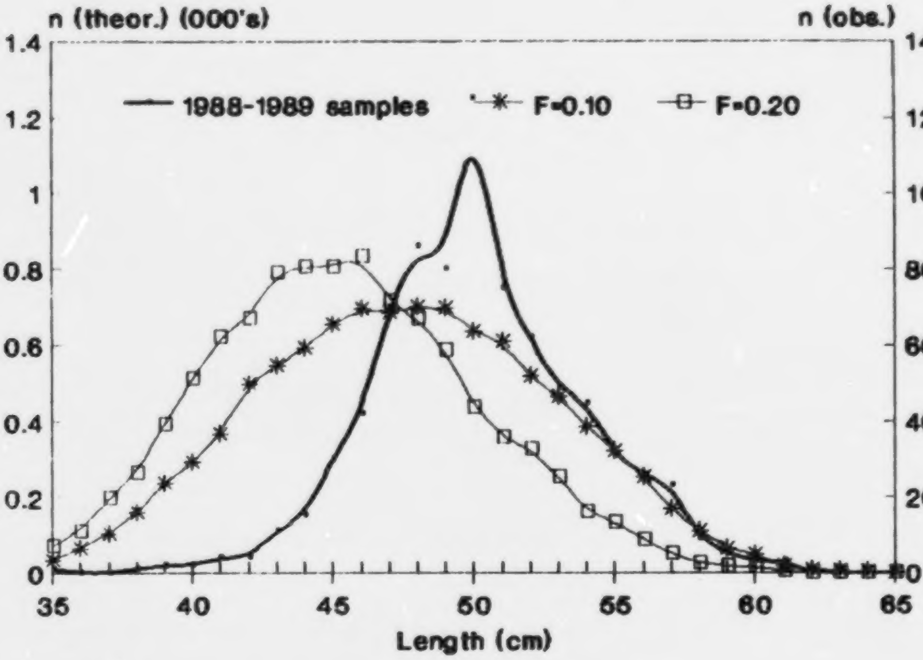


Fig. 10.15. Theoretical and observed length frequencies for male silvergray rockfish from Areas 5A and 5B.

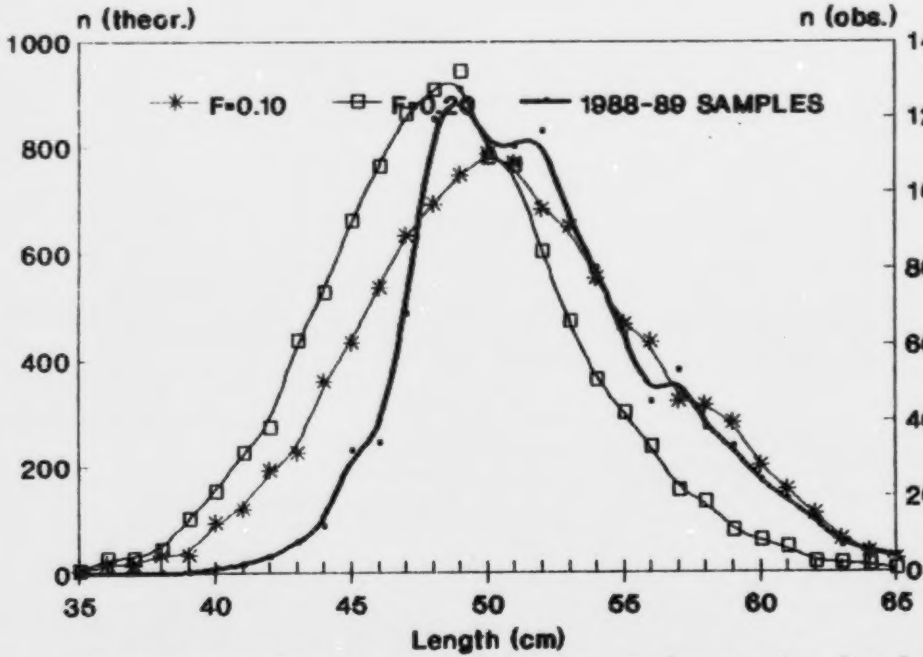


Fig. 10.16. Theoretical and observed length frequencies for female silvergray rockfish from Areas 5A and 5B.

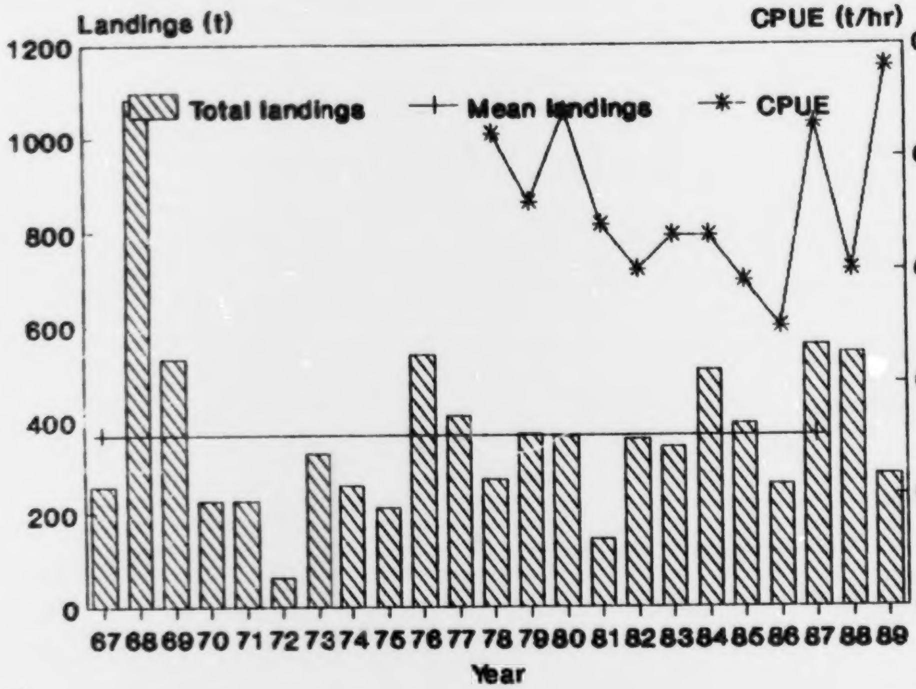


Fig. 10.17. Canary rockfish landings and CPUE in Areas 5A and 5B.

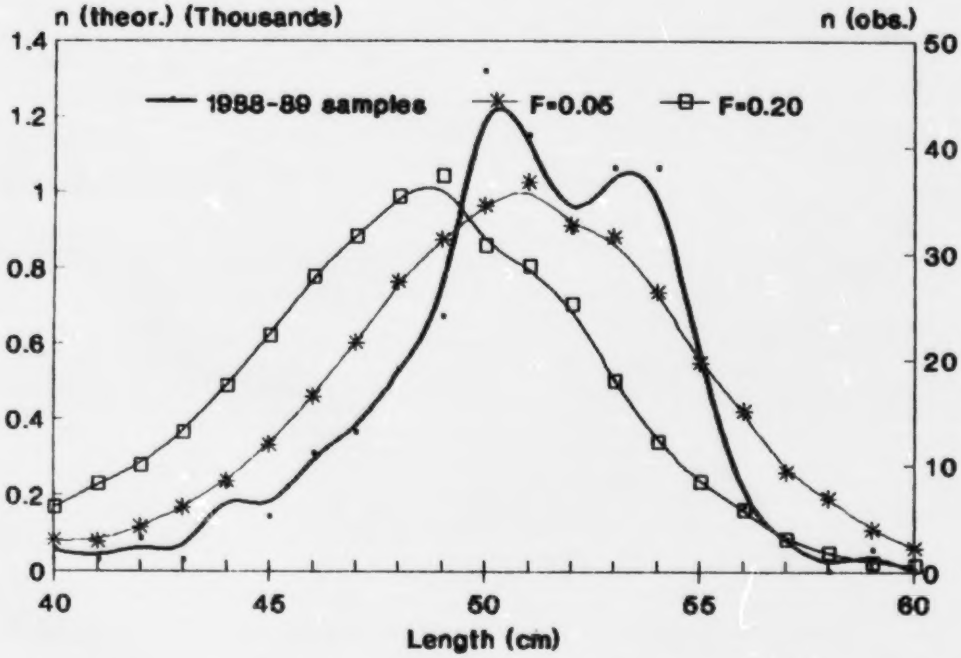


Fig. 10.18. Theoretical and observed length frequencies for male canary rockfish in Areas 5A and 5B.

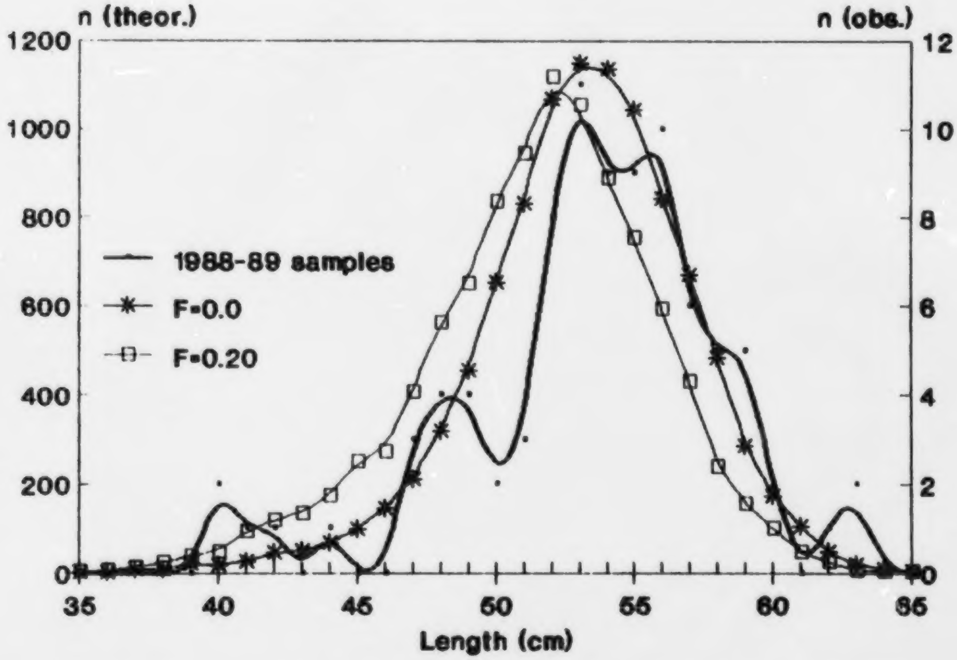


Figure 10.19. Theoretical and observed length frequencies for female canary rockfish in Areas 5A and 5B.

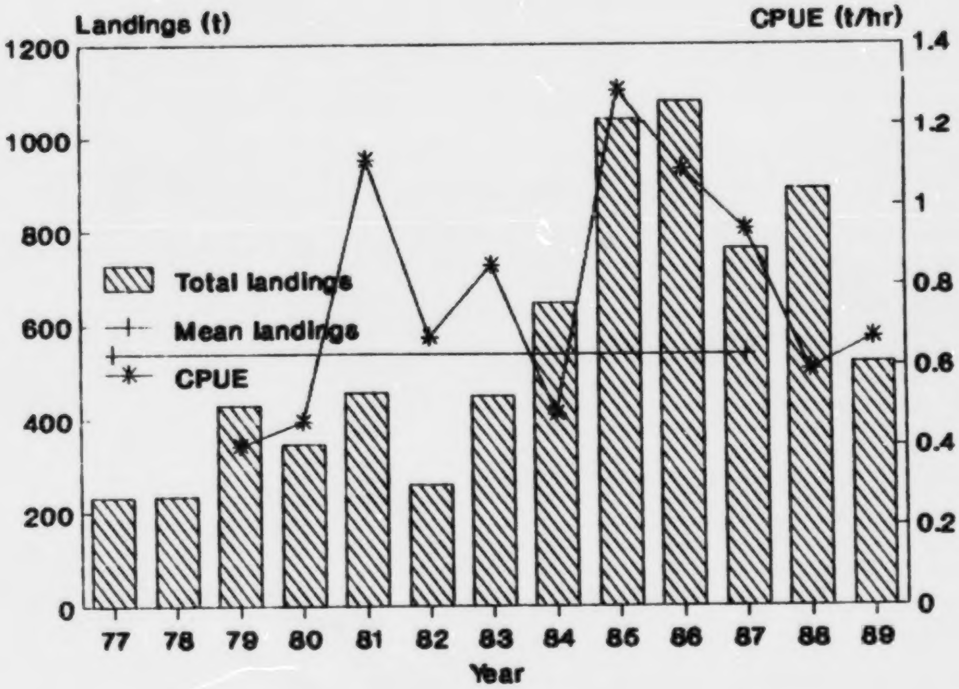


Fig. 10.20. Silvergray rockfish landings and CPUE in Areas 5C and 5D.

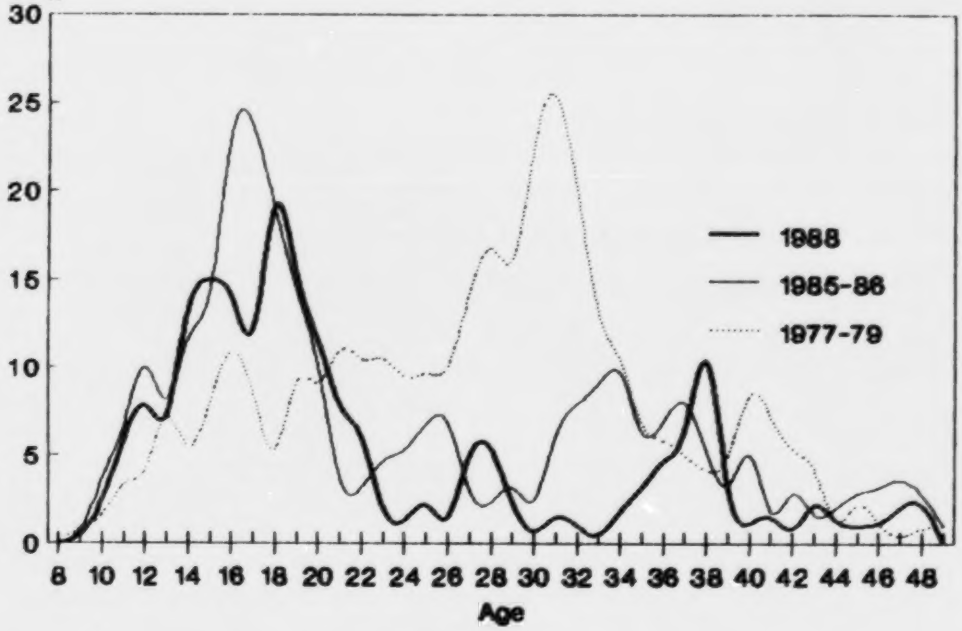


Fig. 10.21. Observed age frequencies for male silvergray rockfish in Areas 5C and 5D.

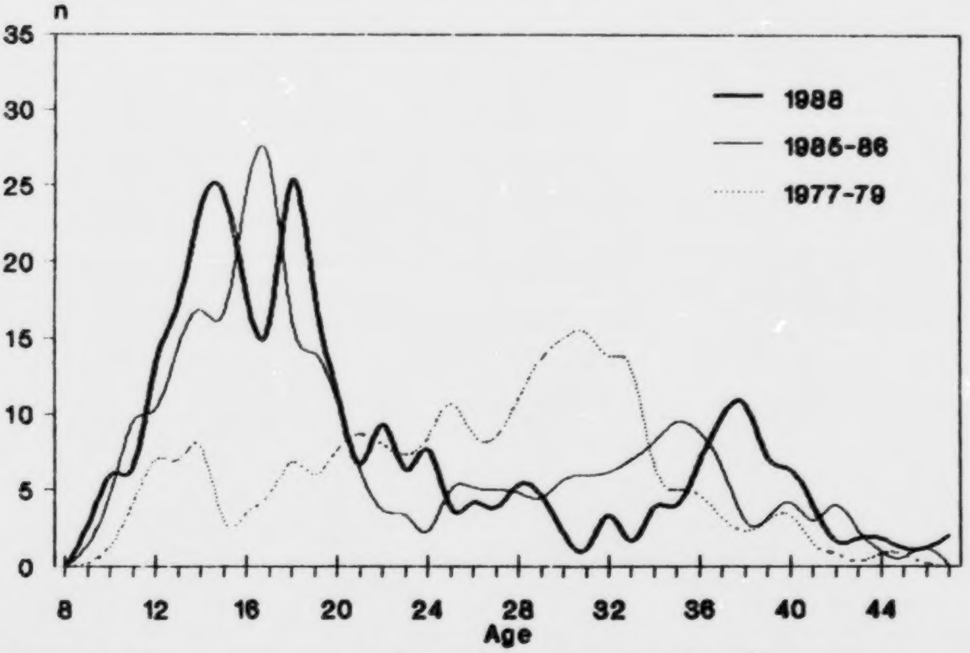


Fig. 10.22. Observed age frequencies for female silvergray rockfish in Areas 5C and 5D.

11.0 INSHORE ROCKFISH (quillback, copper and yelloweye rockfish)

by L. J. Richards and C. M. Hand

11.1 Coastwide

Yield options are not proposed on a coastwide basis.

11.2 Strait of Georgia and Vicinity (Area 4B)

11.2.1 The Fishery

The inshore rockfish fishery occurs throughout the Strait of Georgia and adjacent inside waters of Vancouver Island (Fig 1.1). Most of the commercial vessels use handline/troll or longline gear. The commercial fishery in its present form began to expand about 1977 (Fig. 11.1). At that time a market developed for live rockfish to supply restaurants and retail outlets, primarily in Vancouver's Chinatown. Rockfish are also important to the sport fishery.

There were no restrictions on commercial catch prior to 1987. In 1987, a winter closure for Area 4B was implemented between Jan. 1 and Apr. 15. The closure was extended to Apr. 30 in 1988 and, in addition, Discovery Passage (subareas 13-2 to 13-9, 13-11 and 13-27) remained closed for the entire year. The winter closure was designed to reduce overall levels of effort. It coincided with a lingcod closure and covered the major period of parturition for the most common rockfish species. An incidental catch of yelloweye rockfish (S. ruberrimus) was permitted during this closed period, however, to accommodate a longline dogfish fishery. An experimental 75 t quota was placed on the area 12 rockfish catch in 1987 (excluding the yelloweye rockfish catch), but was not continued in 1988. The sport fishery has been restricted coastwide by a daily bag limit of eight rockfish since 1986.

Quillback rockfish (S. maliger) is the dominant species in the commercial handline/troll fishery and accounts for about 85% (by number) of the catch, based on commercial samples and the logbook program (Hand and Richards 1988). There are minor catches of several other species including copper rockfish (S. caurinus), yellowtail rockfish (S. flavidus), black rockfish (S. melanops), tiger rockfish (S. nigrocinctus), and yelloweye rockfish, as well as lingcod (Ophiodon elongatus) and kelp greenling (Hexagrammos decagrammus). Yelloweye rockfish is the dominant species in the commercial longline catch, with the exception of areas 12 and 17-19, where both handline/troll and longline gear are used to target on quillback rockfish. Quillback rockfish, copper rockfish and yelloweye rockfish account for 54%, 23% and 15%, respectively, of the rockfish sport catch, based on the 1985 creel census (T. Shardlow and T. Hoyt, unpub. data).

11.2.2 Landing Statistics

Historically, most of the rockfish trawl catch was obtained from areas 18, 19 and 20 (Table 11.1). There were also significant trawl catches (over 10 t) in the 1950s and 1960s in area 14 and in the late 1960s and early 1970s in area 17. The area 4B annual trawl catch averaged 98 t between 1954-70. Since 1970, however, the trawl catch has decreased. The 1988 trawl catch is the lowest on record at 4.7 t. In general, the rockfish trawl catch has been incidental to other fisheries, in particular the Pacific cod fishery, although a yellowtail rockfish fishery has existed in area 20.

The rockfish catch by handline/troll and longline gear was less, historically, than the trawl catch, and averaged 65 t annually between 1954-76 (Table 11.2). The catch began to increase in 1976 and peaked at 527 t in 1986. The decrease in 1987 was probably due to the reduction in effort as a result of the winter closure and the area 12 quota (Table 11.4). However, the 1988 catch of 480 t was near the 1986 level. In particular, the area 12 catch increased by 68% between 1987-88. Areas 12 and 13 accounted for 57% of the 1988 line catch.

The sport catch of rockfish, as estimated by the Strait of Georgia creel survey, averaged 120 t annually between 1982-88 (Table 11.3). Areas 12 and 20 were not covered by the survey, and the sport catch from these areas is not documented. The 1988 catch was above average at 136 t (assuming a weight of 0.7 kg/fish). This is 49% of the total commercial line catch from areas monitored by the creel survey.

The sport catch of rockfish is independently monitored by the tidal diary program. This program combines a sport diary and a visitors survey to estimate the total sport catch. The 1988 catch estimate from this program was 229 t. This is 82% of the total commercial line catch from these areas. The estimate of sport landings by this program may be somewhat inflated due to recall bias by survey participants in the tidal diary data. However, the diary program does include catches made from shore and by SCUBA divers that are not considered by the creel survey. The true figure of sport landings in the Strait of Georgia probably lies somewhere between these two estimates.

Predation by sea mammals on rockfish may be significant (P. Olesuik, DFO, pers. comm.). Harbour seal populations have been increasing at an annual rate of 2.5% since 1972. Recent data suggest that rockfish account for 1.1% of the harbour seal diet which amounts to approximately 102 t eaten annually.

To provide a more meaningful analysis of commercial catch and CPUE, statistical areas within Area 4B are grouped by geographical area (Table 11.4). No information on stock delineation is available, although tagging experiments conducted in Puget Sound suggest that adult quillback and copper rockfish are fairly sedentary (Mathews and Barker 1983). CPUE is based on catch and effort by handline/troll and longline from total rockfish landings of at least 50 kg as reported on sales slips (Richards 1988). For the last 6 y, catch and CPUE are also reported with the "red snapper" catch excluded. This is a market category that includes mainly yelloweye rockfish, but may also include canary rockfish (S. pinniger) and other "red" rockfish.

Richards and Schnute (1986) and Richards (1987) found CPUE for quillback rockfish to be strictly proportional to quillback rockfish densities in research surveys. Although the relationship between commercial fishery CPUE and rockfish abundance is not known, it is assumed that trends in CPUE are indicative of trends in abundance. However, the lack of a trend in CPUE does not necessarily indicate a uniform stock size. Due to both rockfish behavior and the nature of the fishery, stock collapse is possible during periods of apparently high CPUE. For example, CPUE could remain high as isolated reefs are progressively exploited.

Trends in catch, CPUE, and effort for area 12 are shown in Table 11.4a. The current area 12 fishery rapidly developed in 1985 with a catch of more than triple that of the previous year. The 1988 catch of 185 t is the highest on record. Similar catches were observed in area 13 in 1983-84 and could not be sustained. Values of CPUE in area 12 have remained relatively constant since the development of the fishery, with the exception of the abnormally high value in 1986. Values of CPUE are lower for the series that excludes the red snapper catch, but the series show similar trends.

In area 13 (Table 11.4b), total rockfish CPUE averaged 58.4 kg/d between 1977-83 during the build-up of the fishery. The maximum catch of 200 t occurred in 1983. Between 1984-87, CPUE declined significantly to an average of 46.1 kg/d (t-test, $p<0.01$), coincident with the decrease in catch. In 1988, CPUE apparently increased again to near pre-1983 levels. This is probably a result of the closure of Discovery Passage which forced vessels to either leave the fishery or to move to less accessible and therefore less exploited regions. Fewer vessels reported qualified landings in area 13 in 1988 than in any other year.

There are no obvious long-term trends in catch or CPUE in Sechelt (areas 15-16, Table 11.4c) or in the Gulf Islands (areas 14, 17-19, Table 11.4d). There was a decrease between 1987-88 in the number of vessels that landed a 50-kg rockfish catch. In Sechelt, the percentage of red snapper in the total rockfish catch increased from 14% in 1985 to 51% in 1988. Red snapper accounted for 20% of the total rockfish catch in the Gulf Islands between 1986-88.

11.2.3 General Biological Information

Biological samples have been collected from the commercial fishery since 1984 (Table 11.5). In area 12, there have been no consistent trends in mean size of quillback rockfish sampled over the course of the fishery. It is not yet clear whether the decrease between 1988-89 is biologically meaningful or whether it simply reflects sample variation. The length distributions of the commercial samples may in part be determined by market preferences; larger fish ("hogs") have a lower value. However, mean lengths obtained from commercial samples are similar to those from research surveys (Richards and Cass 1987, Richards and Hand 1987, Richards et al. 1988). Based on two samples aged to date (1986 and 1988), the mean age in the commercial catch is 25 y with a range in age of 5-60 y.

In area 13, mean size of quillback rockfish decreased consistently between 1984-87. The 1986-87 samples that demonstrate the major decrease were obtained from Discovery Passage. Mean lengths obtained from research fishing surveys in Discovery Passage in 1987-88 were similar (Richards and Hand 1987, Richards et al. 1988). With the closure of Discovery Passage in 1988, fishing effort shifted to other areas. Mean length was considerably higher from the 1988 commercial sample, collected from east of Quadra Island. However, no difference was found in mean size of quillback rockfish caught deeper than 40 m in Discovery Passage or near Stuart Island during the 1988 research survey. Smaller fish were caught in Discovery Passage at depths less than 40 m (Richards et al. 1988).

Only four commercial quillback rockfish samples have been collected from area 17, and none from the remaining areas of the Strait of Georgia. Based on the commercial samples (Table 11.5) and the research program in area 16 (Richards and Cass 1987) and area 17 (Hand and Richards 1987), the size distribution of quillback rockfish landed in these areas appears to be intermediate between the distributions in areas 12 and 13.

An analysis of size-at-maturity was conducted for quillback rockfish from areas 12 and 13 using the method of Schnute and Richards (1990). The area 12 analysis was based on length and maturity data collected during research surveys in 1986-88 (Richards and Cass 1987, Richards and Hand 1988, Richards et al. 1988) and supplemented by a commercial sample from June 1988. Data for area 13 were based on 1986-87 research surveys (Richards and Cass 1987, Richards and Hand 1988) and commercial samples from January 1986 and May 1987. There were no significant differences in size at 50% maturity for male and female quillback rockfish within each area or between areas ($p>0.05$). The complete analysis for area 13 female quillback rockfish is described in Schnute and Richards (1990). They estimated size at 50% maturity to be 292 mm with a 95% confidence interval of 285-298 mm.

For rockfish, fecundity is related to fish size. Recently, Richards and Schnute (1990) developed a model for analyzing fecundity-size data and applied it to the data for copper and quillback rockfish described by Richards and Emmett (1988). There were no significant differences ($p>0.05$) in the fecundity-length relationship between quillback rockfish from area 13 and copper rockfish from areas 13 and 17. However, quillback rockfish from area 17 had a greater fecundity for a given length over most of the range of the data. It is not clear how these differences relate to the numbers of larvae extruded, as the data were collected during an intermediate stage of oocyte development.

With the number of quillback rockfish samples that have now been aged, it is possible to use the age-frequency data to estimate the proportion of the population surviving each year, and hence, total mortality rates. Schnute et al. (1989b, equation 4.8) describe such a model for estimating total annual survival in a stable fishery. In their procedure, an estimate is obtained of the cumulative mortality, beginning at a fixed age of recruitment. The difference in the cumulative mortalities between any two ages gives a prediction for the mortality and survival over the interval. Because of some uncertainties in the ageing, data for the analysis were grouped into 3-y age intervals for ages less than 30 y, and 5-y age intervals for older ages. Maximum likelihood estimates of survival were obtained from a multinomial likelihood function applied to the observed and predicted estimates in each interval (Table 11.6). Separate analyses were conducted for commercial sample data from areas 12 and 13. The 1986-87 data for area 12 were collected during research surveys (Richards and Cass 1987, Richards and Hand 1988). Estimates of survival and mortality were remarkably similar for the two area 12 samples. In contrast, the estimate of survival is significantly lower ($p<0.05$) for the area 13 sample.

To examine among-area differences in growth of quillback rockfish, the von Bertalanffy growth model

$$y = L_\infty(1-e^{-k(t-t_0)})$$

was applied to quillback rockfish length-at-age data. There were no significant differences in maximum likelihood parameter estimates of L_∞, k, and t_0 for male and female quillback rockfish within an area ($p<0.05$) based on a likelihood ratio test.

Furthermore, when the data were combined over sexes, similar parameter estimates were obtained for samples from areas 12 and 13 (Table 11.7). Hence, quillback rockfish populations in areas 12 and 13 have similar growth rates.

Two samples from the yelloweye longline fishery in area 17 were collected in 1988. Yelloweye rockfish in these samples had a mean length of 481 (S.E.=5.3) mm and were considerably smaller than yelloweye rockfish obtained from other regions of the British Columbia coast (Table 11.5). Although ageing techniques have not been validated for this species, the mean age of both samples combined is 33 y. Length at 50% maturity for female yelloweye rockfish is approximately 440 mm.

11.2.4 Condition of the stock

Quillback rockfish stocks in area 12 do not yet exhibit any strong signs of over-exploitation. However, these data should be interpreted cautiously. The 1988 catch in area 12 was the highest on record and similar to a level shown to be non-sustainable in area 13. Approximately 50% of the landings from area 12 are obtained from a region with less than 2% of the fishable shoreline, a situation analogous to the former Discovery Passage fishery (area 13). It is likely that the fishery will collapse before warning signs become evident. If over-exploitation does occur, the consequences for rehabilitation are long-term (at least 10 y for quillback rockfish).

Quillback rockfish stocks in area 13 remain in relatively poor condition. These stocks were depleted by the fishery between 1982-1984. Although CPUE has apparently increased in 1988, it could be misleading as an abundance index. Mean fish size measured in 1988 is considerably smaller than that measured for area 12, although growth rates are similar for the two areas. Furthermore, quillback rockfish mortality rates are significantly higher in area 13. The condition of stocks in Sechelt and the Gulf Islands is less certain, as there have been few biological samples and no clear trends in catch or CPUE.

Yelloweye rockfish account for an increasing proportion of the Area 4B rockfish catch (Table 11.8). Based on the experience of the Alaska yelloweye rockfish fishery, it is unlikely that the yelloweye rockfish stock can sustain increased fishing pressure. These stocks are possibly already showing signs of heavy exploitation, as mean size of yelloweye rockfish from Area 4B is smaller than from other areas of the coast.

11.2.5 Yield Options

Yield options for the inshore rockfish assemblage, excluding yelloweye rockfish, are derived from the historical rockfish catch. It is assumed that increments of 25 t are the minimum that can be managed in a statistical area. A 75-t quota is listed as low risk-sustainable for area 12 and sustainable for area 13 because of the depletion that has already occurred in area 13. The sustainable option for the combined areas is based on the mean catch between 1977-85. There is no evidence for stock declines after at least a 10-year fishery at those levels. The high risk-sustainable option for yelloweye rockfish is based on the catch rates from 1983-1987, which led to the apparent stock depletion. Consideration should also be given to limiting the sport fishery, which accounts for at least 33% of the total sport and commercial line catch. This may be most important near Campbell River where local closures now apply to the commercial fishery.

Yield option	Other Rockfish			Yelloweye
	Area 12	13	14-20,28,29	Area 4B
low risk-sustainable	75 t	50 t	100 t	25 t
sustainable	100 t	75 t	125 t	50 t
high risk-sustainable	125 t	100 t	150 t	75 t

11.3. West Coast Vancouver Island (Area 3C/D)

11.3.1 Landing Statistics

The rockfish line catch off the west coast of Vancouver Island has increased dramatically since 1985, and now fluctuates near Area 4B levels (Fig. 11.1). The handline/troll catch increased in both 1986 and 1987, but decreased in 1988 (Table 11.9). Most of the catch was obtained from areas 11, 23, 24 and 27. The increase in the rockfish longline fishery has been more sudden. Longline catch jumped from 72-420 t between 1985-86 and has remained near that level in 1987-88 (Table 11.10). Although the rockfish longline fishery extends along the west coast of Vancouver Island, the largest catches were recorded from areas 11 and 27. "Red snapper" (mainly yelloweye rockfish) accounts for just over half of the west coast line catch (Table 11.8).

Unlike the Area 4B fishery, much of the rockfish line catch off the west coast of Vancouver Island occurs incidentally to other line fisheries, for example, halibut, dogfish, and lingcod fisheries. A directed rockfish catch was conservatively defined as a catch in which rockfish comprised at least 50% of the landed weight. By this definition, only 57% of the 1988 west coast catch occurred in a directed fishery. The comparable value for Area 4B is 91%. In addition, there are undocumented discards of yelloweye rockfish caught in the halibut fishery. The rate of incidence of yelloweye rockfish in the halibut catch is conservatively estimated at 5% by number, most or all of which is discarded at sea (B. Leaman, PBS, pers. comm.). The present halibut fishery in B.C. is approximately 900,000 fish with about 10% taken off the west coast of Vancouver Island. This would generate a mortality of about 20 t of yelloweye.

Yelloweye rockfish CPUE is based on catch and effort by handline/troll and longline from 'red snapper' landings of at least 50 kg as reported on sales slips. Similarly, other rockfish CPUE is based on line landings of rockfish of at least 50 kg, excluding the red snapper catch. Both yelloweye CPUE and other rockfish CPUE show similar trends (Table 11.8). CPUE has increased steadily since the initial expansion of the fishery, except for the drop in 1987. With such a short time series, trends in CPUE are uninformative.

11.3.2 General Biological Information

No samples from the commercial handline fishery have been collected from this area. Two samples of yelloweye rockfish were collected from the commercial longline fishery, one each in 1988 and 1989. Mean fish sizes, 552 mm and 560 mm, were intermediate between mean sizes in samples from the Strait of Georgia and the Queen Charlotte Islands (Table 11.5).

11.3.3 Yield Options

The low risk option is the mean line catch over the 1956-85 period, prior to the build-up of the fishery. There are no data available from the Canadian fishery to determine appropriate levels for sustainable or high-risk sustainable yields. Furthermore, it is unlikely that the necessary data can be obtained before stocks are over-exploited. Given the longevity of yelloweye rockfish, the consequences of over-exploitation are long-term (at least 20 y) reductions in catch. As an alternative, sustainable and high-risk sustainable yields are based on harvest levels for the Southeast Alaska directed demersal rockfish fishery. A directed fishery for demersal rockfish began in Southeast Alaska in 1979. The fishery increased rapidly and stocks in that area now show signs of depletion (V. O'Connell, ADF&G, pers. comm.).

The Southeast Alaska coastline is roughly equivalent to the British Columbia coast, not including the Strait of Georgia. The Southeast Alaska harvest limit of 530 t for 1989-90, based on their historical yields, is therefore assumed to be sustainable for the directed British Columbia rockfish fishery. The high risk-sustainable option is assumed to be two-thirds of the Southeast Alaska preliminary harvest limit of 940 t used as the regional harvest objective for 1987-88. Alaska biologists now consider this higher limit to be non-sustainable. One third of the yield is assigned to the west coast of Vancouver Island fishery, in proportion to its area coverage, relative to the entire coast. In addition, yield options have been increased to compensate for the estimated 43% of the 1988 rockfish catch taken incidentally to other line fisheries. The Southeast Alaska harvest limit is for the directed fishery only.

Yield Option	Quota (t)
low risk - sustainable	60
sustainable	310
high risk - sustainable	370

11.4. North Coast (Area 5A/B/C/D/E)

11.4.1 Landing Statistics

The rockfish line catch from the North Coast has increased dramatically since 1984, and, in 1988, exceeded the Area 4B and the West Coast catch (Fig. 11.1). The handline/troll fishery has traditionally been small on the North Coast (Table 11.9). Catch gradually increased between 1984-87, and then more than doubled between 1987-88, primarily due to the expansion of the fishery into the Bella Bella region (area 7). This reflects a shift in effort associated with a winter closure in the Strait of Georgia. The rockfish longline fishery has also been increasing since 1984 (Table 11.10). The 1988 catch was the highest on record at 410 t. Most of the catch was obtained near the Queen Charlotte Islands (areas 1-2). Undocumented discards of yelloweye rockfish from the halibut fishery are conservatively estimated at 160 t for the North Coast (see section 11.3.1).

As for the West Coast, rockfish line catches off the North Coast occur incidentally to other line fisheries. A directed rockfish catch was conservatively defined as a catch in which rockfish comprised at least 50% of the landed weight. By this definition, 54% of the North Coast catch occurred in a directed fishery in 1988.

To further examine trends in catch and CPUE, the North Coast was divided into three regions, the Queen Charlotte Islands (areas 1-2), the 'North coast' (areas 3-5) and the Central coast (areas 6-10). Red snapper CPUE is based on catch and effort by handline/troll and longline from red snapper landings of at least 50 kg as reported on sales slips. Similarly, other rockfish CPUE is based on line landings of rockfish of at least 50 kg, excluding the red snapper catch. A longline fishery for red snapper appears to be developing in the Queen Charlotte Islands, where catch and CPUE have been generally increasing since about 1985 (Table 11.8). Catch in the 'North Coast' is low and there are no clear trends in CPUE. Catch and CPUE from the central coast are both increasing, as is typical of the developmental stage of a fishery.

11.4.2 General Biological Information

Two rockfish samples have been collected from the commercial handline fishery in area 7. Quillback rockfish accounted for 89% of the number of fish in the samples, and there were small numbers of copper rockfish, yelloweye rockfish and kelp greenling. The quillback rockfish had a mean size comparable to those sampled from area 13 (Table 11.5). Quillback rockfish otoliths collected from the 1988 sample have been aged to date. Survival rates for quillback rockfish sampled from area 7 are not significantly different from those obtained for fish sampled from area 12 (Table 11.6). However, quillback rockfish from area 7 grow at a significantly slower rate and attain a smaller maximum size than do fish from areas 12 and 13 ($p<0.001$) (Table 11.7).

Two yelloweye rockfish samples were collected from the commercial longline fishery along the west coast of the Queen Charlotte Islands (area 2). Mean fish sizes, 598 mm and 621 mm, were larger than mean sizes for samples collected from the Strait of Georgia and the West Coast (Table 11.5).

11.4.3 Yield Options

The low risk-sustainable yield is the average line catch between 1974-84, prior to the increase in the fishery. The sustainable and high risk-sustainable yields are based on harvest levels for the Southeast Alaska directed demersal rockfish fishery (see section 11.3.3). Two-thirds of the yield is assigned to the North Coast, in proportion to the North Coast area relative to the entire coast. In addition, yields have been increased to account for an estimated 46% of the 1988 catch in non-directed rockfish fisheries.

Yield Option	Quota (t)
low risk - sustainable	120
sustainable	650
high risk - sustainable	770

Table 11.1. Rockfish trawl catch (t) for Area 4B by statistical area, from Groundfish data files, 1954-88.

	Statistical Area											
Year	12	13	14	15	16	17	18	19	20	28	29	Area 4B Total
1954	5.0	0.3	29.5	0.0	0.0	7.7	11.4	0.7	60.7	0.0	4.8	120.1
1955	1.5	0.1	12.1	0.0	0.1	8.4	87.1	1.0	19.5	0.0	0.8	130.5
1956	5.6	0.6	15.3	0.0	0.0	9.1	4.3	17.2	18.1	0.0	1.4	71.6
1957	0.9	0.3	14.5	0.2	0.0	8.5	4.5	0.5	1.2	0.1	2.6	33.3
1958	1.2	0.8	8.0	0.0	0.0	9.9	2.0	3.1	27.2	0.0	1.2	53.3
1959	1.0	0.9	6.2	0.0	0.0	8.3	16.1	48.3	77.5	0.0	0.7	159.0
1960	0.8	0.3	7.2	0.0	0.1	6.1	8.3	7.6	144.8	0.0	0.7	175.7
1961	1.6	0.1	11.1	0.2	0.3	7.7	15.5	6.0	61.0	0.0	0.8	104.1
1962	2.4	0.8	9.0	0.0	0.5	9.1	12.6	0.3	56.9	0.0	1.0	92.7
1963	0.1	1.5	10.5	0.0	0.0	7.4	14.6	0.9	17.3	0.0	0.4	52.8
1964	0.3	5.0	5.7	0.0	0.0	8.9	20.1	4.5	71.4	0.0	1.2	117.1
1965	0.5	1.1	8.3	0.0	0.0	2.1	9.6	4.0	38.6	0.0	1.0	65.3
1966	2.2	0.0	7.5	0.0	0.0	1.7	7.8	0.8	118.8	0.0	0.0	138.8
1967	2.3	1.2	4.5	0.0	0.0	2.9	5.2	0.7	31.8	0.0	0.1	48.9
1968	1.4	0.0	6.3	0.0	0.0	21.7	4.2	0.9	64.4	0.0	0.1	98.9
1969	0.8	1.2	9.1	0.0	0.0	4.4	5.4	2.4	75.5	0.0	0.3	99.0
1970	0.0	0.0	5.9	0.0	0.0	12.5	7.8	0.1	75.9	0.0	0.2	102.4
1971	0.1	0.1	6.4	0.0	0.0	9.1	7.0	0.4	10.5	0.0	0.6	34.2
1972	0.0	0.0	6.1	0.0	0.0	7.4	2.9	0.1	29.1	0.0	0.0	45.6
1973	0.5	1.9	3.1	0.0	0.0	12.1	2.9	0.0	3.5	0.0	0.1	24.0
1974	0.0	0.2	5.3	0.0	0.0	5.6	5.7	0.1	4.1	0.0	0.6	21.7
1975	0.1	1.8	4.0	0.0	0.0	2.3	7.6	2.4	10.9	0.0	0.0	29.1
1976	0.2	1.0	3.3	0.0	0.0	2.0	9.1	1.1	14.3	0.0	0.0	31.1
1977	1.2	0.8	5.2	0.0	0.0	2.6	7.9	2.0	10.5	0.0	0.0	30.1
1978	9.8	0.4	5.6	0.0	0.0	1.7	12.3	5.7	16.6	0.0	0.1	52.0
1979	0.4	0.0	3.8	0.0	0.0	3.6	15.7	17.5	82.9	0.0	0.4	124.2
1980	0.1	0.1	1.2	0.0	0.0	5.2	6.4	6.1	20.7	0.0	0.1	39.8
1981	0.6	0.0	1.8	0.0	0.0	2.6	11.0	15.8	17.9	0.0	1.5	51.1
1982	0.0	0.1	2.9	0.0	0.1	5.2	9.7	11.5	19.2	0.0	0.2	48.7
1983	2.7	0.1	0.9	0.0	0.0	3.5	11.1	4.2	4.8	0.0	0.1	27.4
1984	0.1	0.0	1.1	0.0	0.0	1.8	15.4	7.7	12.3	0.0	0.4	38.8
1985	0.2	0.0	0.9	0.0	0.0	2.2	6.6	6.8	8.5	0.0	0.1	25.2
1986	0.0	0.1	1.1	0.0	0.0	4.3	5.0	1.4	33.8	0.0	0.0	45.6
1987	0.0	0.1	2.2	0.0	0.1	3.5	1.9	2.4	4.6	0.0	0.0	14.8
1988	0.0	0.0	0.3	0.0	0.0	0.8	0.8	0.8	2.7	0.0	0.1	4.7

Table 11.2. Rockfish handline/troll and longline catch (t) for Area 4B by statistical area, from British Columbia catch statistics, Annual Reports, 1954-88.

	Statistical Area											
Year	12	13	14	15	16	17	18	19	20	28	29	Area 4B Total
1954	6.3	6.8	0.8	0.6	6.8	15.1	6.1	0.0	0.0	0.4	0.0	43.0
1955	6.3	6.8	0.8	0.6	6.8	15.1	6.1	0.0	0.0	0.4	0.0	43.0
1956	6.8	2.0	0.2	1.0	5.0	19.0	5.5	0.1	0.1	0.0	0.2	39.9
1957	5.7	6.1	2.5	2.8	14.5	26.0	7.0	6.5	0.0	0.1	1.1	72.4
1958	8.0	10.8	9.8	6.0	15.4	29.3	15.8	6.3	3.2	0.0	2.0	106.6
1959	13.2	16.4	9.3	10.7	10.9	36.4	4.0	3.9	0.5	0.1	0.7	106.1
1960	10.1	20.1	4.8	11.8	11.2	19.8	3.5	3.2	0.9	0.4	0.1	86.0
1961	10.4	16.9	6.5	2.7	4.9	16.2	3.2	1.4	0.6	0.1	1.5	64.5
1962	52.8	15.1	4.7	5.8	3.1	19.7	2.4	2.5	0.6	0.2	0.5	107.5
1963	39.1	7.8	3.7	1.6	6.2	16.4	2.8	0.9	0.2	0.0	0.2	78.8
1964	11.1	4.6	2.1	0.9	12.8	8.8	2.8	1.1	0.7	0.0	0.1	45.1
1965	10.2	3.5	2.1	0.1	10.3	9.3	3.3	0.4	0.1	0.0	0.3	39.6
1966	4.2	3.6	3.8	0.5	13.0	4.1	4.1	0.2	0.1	0.1	0.0	33.8
1967	9.9	7.6	5.9	3.4	16.7	6.3	1.9	0.1	0.1	0.0	0.0	51.9
1968	11.8	8.2	5.0	1.0	19.0	10.3	1.4	0.2	0.1	0.0	0.0	57.0
1969	25.3	12.0	3.8	3.5	16.6	8.8	4.2	0.3	0.9	0.0	0.1	75.6
1970	23.8	16.9	4.0	5.0	9.8	16.1	1.5	0.6	0.8	0.0	0.0	78.9
1971	28.6	9.4	2.7	5.1	6.8	12.2	1.0	0.3	0.0	0.0	0.0	66.1
1972	26.3	14.1	5.0	4.5	11.8	12.2	0.9	0.5	0.0	7.0	0.0	82.3
1973	30.8	11.4	2.7	7.2	14.9	10.5	1.4	0.0	0.0	12.3	0.0	91.2
1974	8.6	7.3	3.2	8.2	2.8	12.2	2.8	0.0	0.0	0.8	0.0	45.7
1975	5.9	5.9	2.3	6.3	1.9	9.1	4.5	0.5	0.0	1.7	0.0	37.9
1976	10.9	10.4	5.0	7.7	2.7	7.3	2.7	0.0	0.9	3.3	0.0	50.9
1977	55.8	17.7	9.1	15.9	5.4	10.9	15.0	2.7	0.9	13.8	1.0	148.1
1978	21.0	30.0	7.0	15.0	19.0	29.0	32.0	5.0	1.0	1.0	3.0	163.0
1979	40.0	63.0	12.0	16.0	22.0	37.0	46.0	5.0	1.0	2.0	5.0	249.0
1980	27.0	43.0	10.0	12.0	20.0	20.0	35.0	5.0	0.0	3.0	0.0	177.0
1981	20.7	55.6	12.0	27.2	29.7	20.8	40.1	3.1	0.0	0.4	1.4	211.0
1982	21.5	106.3	9.0	74.5	34.2	10.0	18.5	2.0	0.0	0.2	1.7	277.9
1983	11.6	199.7	9.4	11.4	30.4	15.0	16.1	1.9	0.3	1.8	0.8	298.4
1984	32.7	198.0	3.3	13.3	22.8	38.0	23.6	7.7	2.0	0.2	1.4	342.6
1985	106.3	153.1	4.9	17.6	22.9	84.5	34.7	9.0	1.4	0.0	1.7	436.1
1986	135.3	142.7	18.4	24.9	58.7	63.0	45.8	23.7	9.3	0.0	5.3	527.1
1987	109.8	116.7	9.4	18.7	17.8	30.4	30.1	35.0	12.3	12.8	10.7	403.7
1988	184.7	90.2	12.3	25.6	36.9	50.4	23.9	26.7	17.7	0.0	11.6	480.0

Table 11.3. Rockfish sport catch (t)[a] for the Strait of Georgia by statistical area from the creel survey (Shardlow and Hoyt, unpub. data), and the total for the same areas from the sport diary program and visitors survey (Bijsterveld, unpub. data), 1982-88.

	Statistical Area[b]										
Year	13	14	15	16	17	18	19	28	29	Creel Total	Tidal Diary Total
1982[c]	17.5	10.9	3.2	27.0	18.3	20.9	8.4	25.3	6.1	136.3	198.2[d]
1983	26.0	12.5	2.7	29.4	16.4	16.5	26.1	10.4	6.4	146.4	130.7
1984	15.9	10.1	3.0	11.3	24.7	14.2	18.7	7.6	5.6	111.1	140.0
1985	10.1	8.7	1.2	27.0	14.5	8.5	14.2	5.0	4.6	93.8	19.6[e]
1986	14.8	14.5	1.9	34.2	12.9	9.0	20.0	4.9	5.0	117.5	302.0
1987	11.5	15.9	2.1	14.4	16.1	10.4	19.5	2.9	2.5	95.4	259.6
1988	17.3	21.0	2.0	26.7	21.4	12.0	24.4	4.2	7.4	136.3	228.6[d]

[a] Converted from pieces using average weight of 0.7 kg.

[b] Areas 12 and 20 are not covered by the creel survey.

[c] Mean of 1980-82 estimates from creel survey.

[d] Visitors component estimated as the mean of 1983-1987.

[e] Sport diary component not available.

Table 11.4. Total rockfish line catch (t), rockfish line catch excluding the 'red snapper' catch (QB/CO), rockfish CPUE (kg/d), rockfish CPUE with 'red snapper' excluded, effort (d), and the number of vessels that made a 50-kg qualified catch by geographical area, 1967-88. Effort is calculated from the ratio of total rockfish catch to CPUE.

a) Area 12, Port Hardy

	Catch (t)		CPUE			
Year	Total	QB/CO	Total	QB/CO	Effort	No. of Vess.
1967	9.9		89.4		111	
1968	11.8		34.3		344	
1969	25.3		64.0		395	
1970	23.8		72.3		329	
1971	28.6		65.7		435	
1972	26.3		41.2		638	
1973	30.8		102.4		301	
1974	8.6		36.6		235	
1975	5.9		36.2		163	
1976	10.9		47.5		225	
1977	55.8		80.8		691	
1978	21.0		52.1		403	
1979	40.0		55.0		728	71
1980	27.0		48.7		554	45
1981	20.7		57.3		361	42
1982	21.5		54.9		392	47
1983	11.6	8.4	63.1	52.0	184	37
1984	32.7	17.1	78.9	49.3	415	60
1985	106.5	80.0	70.1	56.6	1519	65
1986	135.3	100.5	86.9	69.1	1556	66
1987	109.8	89.9	71.1	59.6	1545	104
1988	184.7	136.9	74.4	58.6	2483	92

Table 11.4. (cont'd)

b) Area 13, Campbell River

	Catch		CPUE			
Year	Total	QB/CO	Total	QB/CO	Effort	No. of Vess.
1967	7.6		47.8		159	
1968	8.2		60.7		135	
1969	12.0		106.4		113	
1970	16.9		59.6		283	
1971	9.4		61.2		154	
1972	14.1		45.8		308	
1973	11.4		63.7		179	
1974	7.3		52.2		140	
1975	5.9		81.3		73	
1976	10.4		49.8		209	
1977	17.7		51.1		346	
1978	30.0		56.3		533	
1979	63.0		66.9		942	98
1980	43.0		57.7		743	65
1981	55.6		62.8		885	86
1982	106.3		62.2		1709	114
1983	199.7	186.6	51.5	49.5	3876	127
1984	198.0	180.1	47.3	43.7	4186	125
1985	153.1	124.1	46.4	38.1	3302	101
1986	142.7	134.9	44.8	42.5	3184	87
1987	116.7	110.2	45.7	43.6	2554	125
1988	90.2	81.5	56.2	52.3	1605	54

Table 11.4. (cont'd)

c) Areas 15 and 16, Sechelt

	Catch		CPUE			
Year	Total	QB/CO	Total	QB/CO	Effort	No. of Vess.
1967	20.1		56.1		359	
1968	20.0		76.3		262	
1969	20.1		74.7		269	
1970	14.8		47.5		311	
1971	11.9		32.7		364	
1972	16.3		28.2		578	
1973	22.1		67.7		326	
1974	11.0		61.0		180	
1975	8.2		24.7		333	
1976	10.4		39.3		265	
1977	21.3		71.0		300	
1978	34.0		60.1		566	
1979	38.0		84.2		451	162
1980	32.0		65.1		491	117
1981	56.9		104.9		542	88
1982	108.8		79.9		1361	67
1983	41.8	37.0	63.7	64.5	656	71
1984	36.1	35.4	56.1	55.0	644	81
1985	40.5	34.9	84.7	70.8	478	86
1986	83.6	67.9	95.1	87.7	879	97
1987	36.4	13.8	64.1	35.6	568	79
1988	62.5	30.4	66.0	51.9	947	49

Table 11.4. (cont'd)

d) Areas 14, 17-19, Gulf Islands

	Catch		CPUE			
Year	Total	QB/CO	Total	QB/CO	Effort	No. of Vess.
1967	14.2		40.7		349	
1968	16.9		31.5		536	
1969	17.1		27.9		613	
1970	22.2		38.0		584	
1971	16.2		58.0		279	
1972	18.6		25.4		733	
1973	14.6		36.8		397	
1974	18.2		28.7		634	
1975	16.4		58.9		278	
1976	15.0		49.3		304	
1977	37.7		55.2		683	
1978	73.0		53.7		1360	
1979	100.0		53.5		1871	65
1980	70.0		50.8		1377	54
1981	76.0		69.5		1093	60
1982	39.5		42.1		938	98
1983	42.4	36.8	42.5	39.4	997	43
1984	72.6	66.5	45.7	43.4	1590	41
1985	133.1	114.2	64.4	57.9	2068	42
1986	150.9	117.9	79.6	66.3	1896	47
1987	104.9	81.1	64.2	58.3	1634	151
1988	113.4	90.2	58.5	51.9	1938	97

Table 11.5. Number of quillback and yelloweye rockfish samples obtained from the commercial fishery with sample size, mean length (mm), and standard error by sex, statistical area and year.

Area	Year	No of Samples	Males			Females			Comb.		
			N	Mean	SE	N	Mean	SE	N	Mean	SE
QUILLBACK ROCKFISH (handline gear)											
07	88	1	137	326	3.9	95	317	4.4	232	323	2.9
	89	1	108	329	3.7	72	326	5.2	180	328	3.0
12	84	1	86	391	2.5	139	390	3.7	225	390	2.4
	85	1	140	349	2.5	121	346	2.8	261	348	1.9
	86	2	218	346	4.1	260	374	3.9	479	362	2.8
	87	3	370	351	2.8	392	357	3.1	762	354	2.1
	88	2	212	357	3.9	224	364	3.7	436	361	2.7
	89	2	102	347	4.8	121	356	4.0	571	343	2.0
13	84	3	268	325	2.6	297	328	2.7	565	327	1.9
	85	3	609	322	1.9	495	328	2.0	1105	325	1.4
	86[a]	2	294	314	2.9	314	325	3.0	607	319	2.1
	87[a]	2	268	289	2.7	253	291	3.0	521	290	2.0
	88[b]	2	106	327	4.5	105	334	4.3	211	331	3.1
17	86	2	123	340	4.1	199	353	3.1	323	349	2.5
	89[c]	2	-	-	-	-	-	-	149	335	4.5
YELLOWEYE ROCKFISH (longline gear)											
02	86	1	106	608	6.3	154	591	4.5	260	598	3.7
	89	1	52	640	7.8	54	602	8.3	106	621	6.0
07	89	1	159	557	5.6	69	541	6.2	228	552	4.4
25	88	1	36	539	13.6	63	559	8.5	100	552	7.3
27	89	1	40	556	9.1	60	555	8.0	100	560	6.0
17	88	2	110	488	8.0	115	475	6.9	225	481	5.3

[a] west of Quadra Island (Discovery Passage).
[b] east of Quadra Island.
[c] Data from an on-board observer.

Table 11.6. Approximate 95% confidence intervals for the proportion of the population surviving each year and the corresponding estimates of instantaneous total mortality rate (Z) from quillback rockfish age-frequency data. Samples are identified by the nearest port, statistical area, year(s), and sample size. To enable among-sample comparisons, ages 12 and older were included in all analyses.

Port	Area	N	Year	Survival	Z
Bella Bella	7	223	88	0.93-0.95	0.06
Telegraph Cove	12	596	86-87	0.94-0.94	0.06
Telegraph Cove	12	207	88	0.93-0.94	0.06
Campbell River	13	412	86	0.90-0.92	0.09

Table 11.7. Maximum likelihood estimates of von Bertalanffy growth parameters L_∞, k, and t_0 for quillback rockfish length-at-age data collected from three areas. Samples are identified by the nearest port, the statistical area, year(s), and sample size. Units for L_∞, k, and t_0 are mm, y^{-1}, and y, respectively. As predicted curves for male and female rockfish are not significantly different within each area ($p<0.05$), data have been combined across sexes.

Port	Area	Year	N	L_∞	k	t_0
Bella Bella	07	88	232	391	0.054	-10.6
Telegraph Cove	12	86-88	805	419	0.068	-7.8
Campbell River	13	84,86	601	405	0.071	-7.4

Table 11.8. 'Red snapper' (primarily yelloweye rockfish) handline/troll and longline catch (t), CPUE (kg/d) and effort (d) and other rockfish catch (t), CPUE (kg/d) and effort (d) by geographic region. CPUE is based on landings of at least 50 kg. Effort is calculated from the ratio of catch to CPUE. Source: British Columbia catch statistics data files, 1983-1988.

	'Red Snapper'			Other Rockfish		
Year	Catch	CPUE	Effort	Catch	CPUE	Effort
A) East Coast Vancouver Island, Statistical Areas 12-20, 28, 29						
1983	26.8	44.0	609	270.9	49.3	5495
1984	46.3	37.9	1222	300.8	44.8	6714
1985	83.2	35.2	2364	354.8	50.2	7068
1986	93.6	57.9	1616	433.3	59.5	7282
1987	91.5	56.5	1619	312.1	53.1	5878
1988	124.2	48.8	2545	355.9	55.5	6413
B) West Coast Vancouver Island, Statistical Areas 11, 21-27						
1983	33.4	69.5	480	65.9	40.2	1639
1984	66.7	121.2	550	71.0	51.0	1392
1985	111.2	152.4	730	90.2	69.2	1303
1986	362.4	202.3	1791	216.9	111.5	1945
1987	301.2	138.3	2178	293.7	88.9	3304
1988	272.2	215.2	1265	216.5	103.5	2092
C) Queen Charlotte Islands, Statistical Areas 1-2						
1983	17.6	63.0	279	22.0	40.1	549
1984	26.5	51.7	513	72.1	137.2	526
1985	76.2	136.9	557	74.4	106.6	698
1986	110.6	185.0	598	82.3	131.4	626
1987	105.2	160.2	657	150.9	128.2	1177
1988	181.2	224.0	809	107.9	137.5	785
D) North Coast, Statistical Areas 3-5						
1983	9.0	56.5	159	4.9	23.2	211
1984	19.9	131.7	151	6.2	28.3	219
1985	22.9	75.5	303	16.4	40.4	406
1986	17.2	70.3	245	22.3	70.9	315
1987	45.7	103.2	443	24.9	57.4	434
1988	47.1	105.7	446	16.0	55.2	290

Table 11.8. (cont'd)

	'Red Snapper'			Other Rockfish		
Year	Catch	CPUE	Effort	Catch	CPUE	Effort
E) Central Coast, Statistical Areas 6-10						
1983	4.3	45.0	96	10.2	51.4	198
1984	6.9	72.4	95	10.5	40.7	258
1985	14.7	56.0	263	24.6	62.3	395
1986	19.8	74.5	266	42.5	85.9	495
1987	45.7	93.8	488	76.5	77.8	983
1988	68.8	101.1	681	106.3	80.0	1329

Table 11.9. Rockfish handline/troll catch (t) by statistical area for the north coast and the west coast of Vancouver Island, from British Columbia catch statistics, Annual Reports, 1956-88.

	Statistical Area																	NC	WC
Year	1	2	3	4	5	6	7	8	9	10	11	21	23	24	25	26	27	1-10	11, 21-27
1956	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.1	1.6	0.2	0.0	0.5	0.4	2.4
1957	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.5	0.4	0.7	2.1	0.0	4.9
1958	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.7	0.8	0.6	1.3	0.1	4.6
1959	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	2.8	1.0	0.9	0.7	0.0	6.1
1960	0.0	0.0	0.0	0.1	0.0	0.0	0.5	0.1	0.1	2.4	0.2	0.0	0.5	3.9	1.1	0.5	1.5	3.2	7.7
1961	0.0	0.0	0.0	0.0	0.0	0.0	6.6	0.3	0.2	2.3	0.1	0.0	1.2	1.5	1.1	0.6	2.9	9.4	7.4
1962	0.2	0.0	0.0	0.0	0.0	0.0	6.3	0.5	0.2	3.3	0.7	0.5	2.4	7.5	3.6	1.9	4.6	10.5	21.2
1963	0.1	0.0	0.0	0.0	0.5	0.4	8.2	3.9	1.4	2.9	4.0	0.4	5.2	1.3	4.6	3.5	4.9	17.4	23.0
1964	0.0	0.4	0.0	0.0	0.0	0.0	2.5	0.5	0.3	0.0	0.0	0.1	0.8	0.3	0.2	0.3	3.0	3.7	4.7
1965	0.0	0.0	0.0	0.0	0.1	0.6	0.0	0.9	0.0	0.4	0.4	0.2	1.0	0.8	0.6	0.9	1.5	2.0	5.4
1966	0.0	0.0	0.0	0.0	0.3	0.0	1.0	0.6	0.0	0.8	1.8	0.1	0.7	0.1	0.9	1.2	1.1	2.7	5.9
1967	0.1	0.0	0.0	0.0	0.1	3.8	2.9	0.6	0.1	2.0	0.2	0.0	1.1	1.8	1.6	2.3	0.7	9.6	7.7
1968	0.0	0.0	0.0	0.0	0.0	0.2	0.4	1.9	1.3	0.4	0.1	0.2	0.8	1.0	1.7	0.8	2.7	4.2	7.3
1969	0.0	0.0	0.0	0.0	0.0	0.5	0.9	0.0	1.0	2.1	0.0	1.2	1.5	4.7	3.7	2.0	1.8	4.5	14.9
1970	0.0	0.1	0.6	0.0	6.8	2.7	17.3	2.3	2.0	0.5	0.0	2.3	2.5	7.3	5.4	6.8	7.0	32.3	31.3
1971	0.0	0.1	0.1	0.0	3.4	1.4	6.8	1.3	0.5	0.3	0.8	1.6	5.3	3.8	2.9	2.7	0.7	13.9	17.8
1972	0.0	0.0	0.0	0.0	9.6	4.9	7.5	2.4	0.0	0.7	2.0	1.8	9.7	10.7	9.5	15.6	15.9	25.1	65.2
1973	0.5	2.3	0.2	0.5	0.2	0.2	0.9	0.5	0.5	0.2	0.9	1.4	6.4	6.8	0.5	8.2	4.1	6.0	28.3
1974	0.5	1.1	0.2	0.5	0.5	0.9	0.9	1.4	0.2	0.9	2.3	2.7	13.2	20.9	5.9	11.8	5.9	7.1	62.7
1975	0.9	1.0	0.9	0.2	1.4	0.5	1.8	1.4	0.2	0.2	0.5	4.1	14.1	8.6	1.8	6.4	6.8	8.5	42.3
1976	0.2	1.4	0.5	0.5	0.5	0.9	4.1	1.8	0.5	0.9	1.4	2.7	11.8	8.2	1.8	5.9	6.4	11.3	38.2
1977	0.2	3.6	0.5	0.9	1.4	0.9	3.6	1.4	0.9	0.5	11.3	3.6	16.8	12.7	2.7	5.9	5.9	13.9	58.9
1978	2.0	5.0	0.5	6.0	0.5	1.0	2.0	4.0	1.0	1.0	7.0	1.0	14.0	11.0	3.0	6.0	5.0	23.0	47.0
1979	1.0	5.0	1.0	1.0	0.5	3.0	3.0	1.0	1.0	1.0	8.0	3.0	25.0	20.0	7.0	6.0	9.0	27.5	78.0
1980	4.0	3.0	3.0	4.0	4.0	4.0	4.0	0.5	1.0	1.0	7.0	4.0	18.0	16.0	6.0	7.0	12.0	28.5	70.0
1981	2.4	5.3	0.4	1.2	0.7	1.2	0.9	1.2	0.2	0.7	3.4	1.0	11.8	26.1	5.2	8.4	8.5	14.2	64.4
1982	1.7	5.4	0.4	1.1	0.8	0.2	1.8	0.5	0.9	0.4	5.8	2.7	6.9	14.1	6.8	4.5	11.6	13.2	52.4
1983	3.1	2.0	0.8	4.7	0.3	3.1	0.8	2.3	1.6	1.5	8.5	5.2	17.1	15.3	8.7	7.5	12.3	13.2	66.1
1984	3.8	6.7	6.0	2.6	6.7	3.3	2.2	2.5	0.0	0.2	8.1	0.7	6.5	9.8	1.7	2.7	24.0	34.0	53.5
1985	1.5	4.2	1.3	10.7	1.4	5.4	5.5	0.4	0.1	4.1	12.6	0.2	13.6	11.3	2.6	6.6	27.9	34.6	74.8
1986	3.4	4.6	0.2	7.0	4.3	6.7	7.4	1.3	0.4	1.1	9.2	2.2	31.2	50.8	9.6	10.6	45.6	36.4	159.2
1987	2.9	5.2	1.4	6.1	4.5	8.1	3.6	6.4	0.4	12.3	37.0	5.8	22.4	62.6	37.1	13.1	46.1	50.9	224.1
1988	3.6	2.2	5.7	3.9	22.1	11.9	49.2	6.5	10.1	2.4	23.7	7.2	12.3	26.6	5.2	6.4	18.7	117.6	100.1

Table 11.10. Rockfish longline catch by statistical area for the north coast and the west coast of Vancouver Island, from British Columbia catch statistics, Annual Reports, 1956-88.

Year	Statistical Area																	NC	WC
	1	2	3	4	5	6	7	8	9	10	11	21	23	24	25	26	27	1-10	11, 21-27
1956	0.2	1.5	0.0	0.1	0.0	0.6	3.1	0.2	0.3	1.0	0.7	0.1	0.6	1.5	0.0	2.2	18.8	7.0	23.9
1957	1.2	7.9	0.3	0.0	0.0	0.2	3.9	1.4	0.0	0.0	0.0	0.0	2.9	6.8	3.1	3.9	23.4	14.9	40.1
1958	0.1	0.5	0.1	0.0	0.0	0.3	0.6	1.5	0.0	0.0	0.0	0.8	1.0	0.0	6.0	6.8	17.7	3.1	32.3
1959	0.1	0.7	0.0	0.0	0.0	0.1	1.0	1.6	0.2	0.7	0.0	0.0	0.3	2.1	3.0	5.0	25.2	4.4	35.6
1960	1.6	6.9	0.3	1.5	0.1	0.8	0.0	1.5	2.0	0.1	3.0	0.0	0.6	1.2	5.9	5.2	25.7	14.8	41.6
1961	0.8	2.9	0.0	0.0	0.7	1.0	0.3	0.0	0.0	0.6	1.0	0.1	2.2	1.3	5.9	24.4	16.9	6.3	51.8
1962	0.0	13.8	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	1.8	0.4	3.2	2.5	5.6	23.5	21.0	15.4	58.0
1963	0.0	13.2	0.0	1.9	0.4	2.2	3.9	1.2	0.0	0.1	0.1	0.0	2.8	1.4	0.9	13.6	11.2	22.9	30.0
1964	0.0	2.5	0.0	0.2	0.0	0.2	0.0	0.3	0.0	0.8	0.7	1.5	1.1	1.0	0.8	8.6	14.9	4.0	28.6
1965	0.0	10.1	0.1	0.7	0.2	1.4	0.1	0.0	1.0	0.0	0.1	0.6	1.2	0.0	1.6	8.9	9.5	13.6	21.9
1966	2.7	3.7	0.0	0.2	0.0	1.1	3.4	0.3	0.4	0.8	0.0	0.1	1.4	0.0	1.7	14.3	8.4	12.6	25.9
1967	0.9	8.4	0.0	0.8	6.4	0.0	1.1	0.8	0.0	0.0	0.0	0.6	1.0	1.5	4.6	18.9	9.1	18.4	35.7
1968	1.5	1.3	0.0	0.0	0.0	0.0	1.2	2.0	0.0	0.0	0.0	0.1	2.7	0.0	1.4	6.7	17.1	6.0	28.0
1969	0.0	10.5	0.0	0.5	0.0	2.9	15.9	1.0	0.2	3.4	1.8	1.3	1.2	0.5	2.7	19.9	0.8	34.4	28.2
1970	0.0	12.7	0.0	0.2	3.8	24.4	9.3	6.8	0.0	0.4	1.2	0.5	4.2	3.6	0.9	8.2	8.4	57.6	27.0
1971	2.0	25.1	0.0	1.1	5.6	4.3	2.7	9.0	3.1	2.0	1.8	0.0	1.2	0.8	0.0	1.9	2.1	54.9	7.8
1972	0.0	19.0	0.0	2.6	4.9	0.3	7.5	6.4	0.5	0.0	6.0	0.3	1.1	0.0	0.5	8.6	7.2	41.2	23.7
1973	0.0	11.5	2.7	2.7	8.8	8.2	0.2	6.1	0.0	3.4	6.1	0.7	0.7	0.7	0.7	3.4	7.5	43.6	19.8
1974	0.7	36.3	0.7	8.8	11.6	15.0	0.2	4.1	0.0	1.6	3.4	0.0	0.7	0.7	0.0	1.4	4.1	79.0	10.3
1975	3.4	69.4	0.7	8.2	7.5	6.1	8.2	2.0	2.0	4.1	2.7	1.4	1.4	0.0	0.7	0.0	8.8	111.6	15.0
1976	4.1	17.3	0.9	1.8	9.1	5.4	19.5	4.5	0.0	1.4	2.7	2.7	1.8	0.2	0.2	0.2	12.2	64.0	20.0
1977	2.3	29.5	0.5	3.6	7.3	4.5	8.2	5.0	0.2	0.2	23.1	0.2	0.5	0.9	0.5	0.9	15.0	61.3	41.0
1978	3.0	51.0	8.0	14.0	5.0	4.0	11.0	8.0	1.0	0.5	9.0	0.0	1.0	2.0	0.5	1.0	13.0	115.5	26.5
1979	15.0	66.0	2.0	3.0	8.0	6.0	7.0	5.0	1.0	3.0	27.0	1.0	1.0	3.0	3.0	5.0	30.0	116.0	70.0
1980	22.0	61.0	1.0	3.0	4.0	5.0	4.0	3.0	1.0	0.5	20.0	0.5	6.0	0.5	4.0	7.0	22.0	104.5	60.0
1981	17.1	46.4	2.5	3.7	4.7	1.5	1.5	6.2	0.0	0.6	18.1	0.8	1.0	0.5	2.7	4.3	11.1	84.2	38.5
1982	8.2	33.5	2.1	3.7	1.7	5.2	2.6	1.1	0.9	0.3	11.3	0.4	1.1	2.9	0.0	2.0	10.5	59.3	28.2
1983	10.1	26.3	0.6	6.2	1.0	4.2	1.4	1.0	0.0	0.0	9.2	0.5	2.5	0.1	1.4	0.5	23.5	50.8	37.7
1984	8.3	81.6	2.6	12.0	1.0	1.7	2.3	0.6	0.5	2.9	13.8	0.8	6.5	1.3	0.0	0.9	63.3	113.5	86.6
1985	29.5	119.9	6.3	15.2	4.9	9.3	4.9	7.6	0.0	1.6	32.8	3.9	0.0	4.5	5.5	8.7	16.9	199.2	72.3
1986	24.9	159.8	3.7	9.4	14.5	18.2	5.1	19.7	0.1	0.3	55.9	2.0	36.3	56.9	75.6	76.8	116.3	255.7	419.8
1987	55.1	193.5	5.8	12.9	39.9	31.7	19.3	21.6	1.5	17.4	90.8	22.2	30.3	37.8	40.4	37.7	104.0	398.7	363.2
1988	91.4	189.0	9.6	13.3	8.5	37.6	14.6	25.3	0.6	16.9	142.1	6.3	17.1	61.7	31.0	30.5	100.0	409.8	388.7

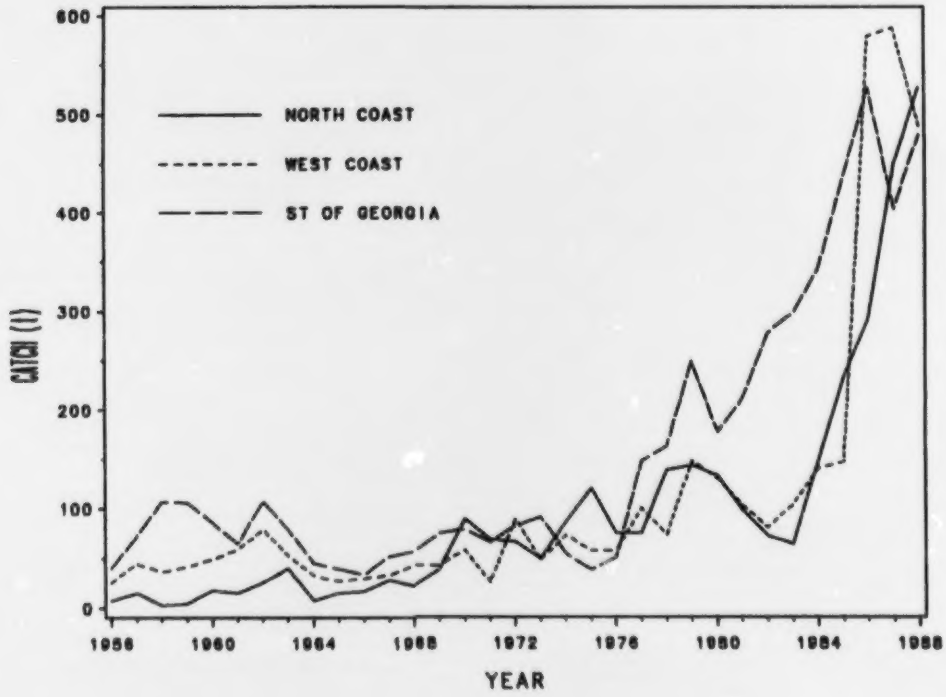


Fig. 11.1. Rockfish handline/troll and longline catch from the Strait of Georgia (areas 12-20, 28, 29) (long dashes), the west coast of Vancouver Island (areas 11, 21-27) (short dashes), and the north coast (areas 1-10) (solid line).

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